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SYMPOSIUM[1]

NATION-WIDE MALARIA ERADICATION PROJECTS IN THE AMERICAS

INTRODUCTORY REMARKS BY THE PRESIDENT

DR. PAUL F. RUSSELL

The most significant aspect of malaria control in the second quarter of this century has been the development of field techniques so effective and so economical that nations have been able to transcend palliative measures and to plan deliberately for the eradication of malaria among their people. Our symposium today highlights some of the most important malaria eradication projects in the New World. But we do not forget that in Italy, Cyprus, Greece, Turkey, Egypt, Mauritius, Ceylon, parts of India, and elsewhere, similar bold and progressive schemes are being carried forward.

Nor have we forgotten that an eradication project was successfully completed in the Americas before the days of DDT. I refer to Barbados where malaria was first discovered in October, 1927. A search soon revealed that *Anopheles albimanus* was widespread in grassy pools, although anophelines had never been known on the island before. Very likely the plasmodia had been carried there by local laborers returning from Cuba, and probably the vector had traveled in the holds of small trading schooners from the Antilles and Demerara. Energetic anti-anopheline measures were taken and were apparently successful in eradicating the vector. Malaria cases were vigorously treated and the records indicate that the disease was eliminated from Barbados.

Also, it should be noted that today from the U. S. A. to Argentina, anti-malaria activities are increasing in tempo, stimulated not only by local interest but by such international agencies as the Pan American Sanitary Bureau-World Health Organization, the Institute of Inter-American Affairs, The Rockefeller Foundation, and others.

Finally, we would make it clear that the basic purpose of this symposium of the National Malaria Society is to emphasize that widespread practical field results indicate that it is now financially possible for a malarious nation to eliminate malaria

[1] Held at the 33rd Annual Meeting of the National Malaria Society, Savannah, Georgia, 8 November 1951.

from its borders within a reasonable time. Of course, trained personnel, an organization, and a will to proceed are required. The most important factor of all is the last named, which involves the setting of the goal of eradication and the developing of the necessary mechanisms and men. In this respect the five leaders, who are presenting our symposium, have been outstanding.

NATION-WIDE MALARIA ERADICATION PROJECTS IN THE AMERICAS

DR. RUSSELL: Our first speaker is so well known to you that I need say very little about him. Graduated from Brown University, *cum laude*, he earned his doctorate of science at Johns Hopkins, where he later became Associate Professor of Protozoology. Then, as Director, Division of Malaria and Hookworm Service, Georgia Department of Public Health, he spent four very active years in practical field work. During World War II, comissioned as a major and rising to a full colonel, he served in many posts, including those of Theater Malariologist in the North African and Mediterranean Areas and in the Philippines. For his outstanding performance of duty he was awarded the Legion of Merit. Since the war he has been in the U. S. Public Health Service and he is now Deputy Officer in Charge, Communicable Disease Center, Atlanta, a post he has filled since 1946.

As teacher, scientist, army medical officer, and public health official, he has had a career of great distinction. His primary interest has been the development of practical health programs, specially for the control of parasitic diseases. He has been one of the chief authors and administrators of the post-war malaria eradication program in the United States, now so well along towards successful conclusion. It gives me great pleasure to present to you our President-elect, Doctor Justin Andrews.

I. THE ERADICATION PROGRAM IN THE U. S. A.

JUSTIN M. ANDREWS*

According to the best evidence available, malaria prevalence has been declining gradually in the United States since 1875 or therabouts (Barber 1929; Boyd 1941; and Ackerknecht 1945). This was some years before it was known how the disease was transmitted or how it could be prevented. During the first third of the present century, it retreated from the North and West to entrench itself in the coastal and fluvial plains of the southeastern quadrant. In spite of this recession, malaria remained such an important cause of disability and unproductiveness that no less than 12 years ago (Williams 1938) its annual cost to the Nation was reckoned at a half billion dollars.

The first recorded suggestion for the "eradication" of this expensive disease was made in 1915 by Dr. Frederick L. Hoffman, Statistician for the Prudential Insurance Company. He read a paper entitled "A Plea for a National Committee on the Eradication of Malaria" (Hoffman 1916) before the Section on Public Health of the Southern Medical Association. This led to the organization of what is now known as the National Malaria Society. The following year Dr. Hoffman addressed a joint session of the SMA, Sections on Medicine and on Public Health, presenting "A Plea and a Plan for the Eradication of Malaria" (Hoffman 1917). He probably used the word "eradication" more as Sir Ronald Ross commonly employed it—to indicate a high degree of control rather than complete elimination of the disease;

* Communicable Disease Center, U. S. Public Health Service, Atlanta, Ga. In this summary of operations and present status, the author has reported the activities of other persons too numerous to be mentioned separately, but whose names appear in the bibliographic references concerning this project. They are thanked herewith. In addition, it is desired to acknowledge the special assistance rendered by Miss Sarah Welch, Analytical Statistician, and Mrs. Jean S. Grant, Editorial Assistant.

but he suggested an extraordinarily comprehensive and prescient approach to the problem involving research, education, and legislation. He urged mosquito and parasite survey, drainage development on a large scale, improved methods of treatment, and a better understanding of the costs of malaria. Perhaps because he was a statistician he was especially impressed with the desirability of instituting more precise and adequate practices in the diagnosis of malaria, in the certification of malaria deaths, and in the reporting of cases.

The person most prominently associated with the proposal on which the National Malaria Eradication Program is based is Dr. L. L. Williams, Jr., Medical Director, U. S. Public Health Service. Interestingly enough, he was not in the country when his official proposition was set forth. But it was his concept, properly acknowledged, which formed the basis of the paper entitled "A Program for the Eradication of Malaria from Continental United States" (Mountin 1944) read before this Society on 18 November 1943, by Dr. J. W. Mountin, and of another by Dr. Stanley B. Freeborn on "The Eradication of Malaria" (Freeborn 1944a) presented on March 23, 1944, at the Conference of State and Territorial Health Officers. As a result of the former, the National Malaria Society passed a resolution recommending that steps be taken to activate the eradication proposal as a sound public health procedure and to meet the impact of repatriated malaria carriers released from the Armed Forces.

Since 1926, Dr. Williams has been intimately concerned with anti-malaria activities within and outside the United States. He directed the malaria field investigations of the Public Health Service, promoted the development of State-level malaria survey-and-control teams, organized, coordinated, or advised regarding major malaria control undertakings in this country, and led malaria expeditions abroad. In 1942 he established in Atlanta the Office of Malaria Control in War Areas to assist the States in reducing the malaria hazard to trainees and workers around areas of military importance. During the period of maximal military preparation and industrial production, drainage, filling, larviciding, entomologic exploration and inspection, and educational activities were carried on by this organization near some 2200 localities of military concern in 19 different States (Andrews 1948b). Federal costs from 1942 through fiscal 1945 totalled about $25,000,000. On military establishments similar malaria control operations were executed under military auspices. This enterprise is generally credited not only with preventing malaria in this country from interfering with the war effort but with nullifying the increase in national malaria prevalence predicted for the early or middle forties (Williams 1941; Freeborn 1944b).

By 1944, service personnel, many of whom had been infected overseas, were returning to their homes in various parts of the country (Freeborn 1944b). In sections where native species of vectoral mosquitoes flourished, it seemed likely, and was proved experimentally (Young *et al.* 1948), that transmission could occur from relapsing veterans to susceptible individuals. By this time, the military use of DDT as a residual insecticide had established its antimalarial effectiveness and economy and in 1945 the compound was made available to the States through the Public Health Service, specifically to prevent the transmission of imported malaria. It was

sprayed on the interior walls and ceilings of rural homes and privies in counties where relatively high malaria mortality was experienced during the five years preceding World War II. This activity was known as the Extended Malaria Control Program and it was carried on for two years. Nearly 2,500,000 house-sprayings were made in 315 counties at a cost of 11.5 million dollars which included some larviciding. Of this amount, State and local governments contributed about 20 per cent.

Thus the stage was set in 1947 for activating the National Malaria Eradication Program, a cooperative effort by State and Federal health agencies to execute the project proposed by Dr. Williams. A number of circumstances favored its chance of success. The spontaneous recession of malaria from the northern and central States proved the physical possibility of eradication. The impressive achievements of Soper and his associates (Soper and Wilson 1942) in exterminating *Anopheles gambiae* and *Aedes aegypti* from large areas in South America had extended the horizons of vector control objectives. World War II created a more general awareness of malaria among the people of this Nation and provided opportunities for improving professional experience in the diagnosis, treatment, and control of the disease. DDT had been shown to reduce the domestic density of anophelines under civilian conditions in this country (Bradley and Fritz 1947) and the failure of post-war malaria outbreaks to develop after its use during the Extended Malaria Control Program was generally conceded to be convincing evidence of its efficacy in preventing transmission. Finally, the reported incidences of malaria morbidity and mortality in the United States were the lowest they had been since the establishment of the Registration Area in 1910 (Andrews 1948a). This appeared to be due to a variety of factors (Andrews 1948b), many of which were dependent upon the prosperous economy and high standards of living which then prevailed. Economic adversity would certainly send throngs of city-dwellers back to anopheline-infested rural areas to live in deteriorated housing without the means for insect-proofing, insecticides, or antimalarial remedies. Under these conditions, malaria might again compound the miseries of depression as a widespread cause of death, sickness, and poverty; unless the agent of paludism had been eliminated from the land. It was clear that this must be done before the favoring influences of the more abundant life had waned.

In planning the eradicative program for this country the possibility of complete annihilation of the vectoral species of Anopheles was dismissed as infeasible. Similarly the elimination of all malaria parasites from the population by mass treatment was not considered because of the technical inadequacies and administrative difficulties involved. The approach as finally developed (Andrews and Gilbertson 1948) was based on two principles, the destruction of endemicity and the prevention of its reestablishment.

It was believed that if the numbers of malaria parasite carriers and of vectoral mosquitoes could be reduced simultaneously, transmission would become less and less likely to occur. If it could be cut down to the point where each consecutive lot of new cases was smaller than the preceding one, the morbidity trend would necessarily be downward. If that negative slope could be maintained, it would ultimately reach the base line and endemic malaria would be eradicated. It was proposed to

effect the decline in transmission by actively promoting improved diagnosis and treatment of cases, and by reducing the household density of anophelines with residual insecticides according to the procedures evolved during the Extended Malaria Control Program.

The second phase of the Eradication Program, preventing the renaissance of endemicity, was to depend upon the activities of what are now known as surveillance-and-prevention teams assigned to State health departments. Ideally, these would consist of an epidemiologist, an entomologist, and an engineer. Their primary responsibilities would be to appraise all reported or discovered cases of malaria and, when these were verified, to conduct such parasitologic and entomologic investigations as the circumstances warranted, and to see that infected individuals were promptly and effectively treated, and that their homes and those of others within flight range were sprayed with DDT.

Thus the argument and plan for national malaria eradication was put before the Bureau of the Budget and the Appropriations Committees of the Congress in 1946. It was stated by representatives of the Public Health Service that in view of existing trends, it seemed probable that endemic malaria might be eradicated by the proposed procedures within a period of five years, if the existing levels of federal and other funds for its control were maintained for that period of time. It was expected that the federal appropriations would comprise about one-half the total cost, the remainder being contributed from State and local sources. It was anticipated that a sharp reduction in program and financing would occur after endemic malaria had disappeared, and that the federally-aided program of post-operational surveillance and prevention would be continued until such time as it could be staffed and supported adequately by the States without federal assistance. The Public Health Service was encouraged to proceed with the proposed plan and on 1 July 1947, initiated the National Malaria Eradication Program with the cooperation of the 13 States* concerned.

Field activities continued according to the administrative and operational patterns developed in the Extended Malaria Control Program. These provided for the federal establishment of broad general policies in conformance to the mandates and appropriations of Congress, with the actual administration of authority and managerial functions remaining at State level. Operating organizations known as State CDC Activities were maintained as supplements to and parts of the State health departments. Federal funds were used to purchase equipment for spraying and transport, materials, and supervisory personnel; State and local contributions were generally used to supply labor. Provisional solutions to operational problems were suggested in the laboratory and tested in the field by members of the Technical Development Services in Savannah, Ga. They sought continuously to improve the efficiency and economy of field procedures. The general use of recent technologic developments and recommended practices was encouraged by centralized training courses for key operations (Anonymous 1948–50a), followed by decentralized training in lower eche-

* Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas.

lons. This instruction was facilitated and expedited by the use of audio-visual training aids produced for the purpose (Anonymous Undated).

While there was some variation in practice from State to State, the usual procedure was for 5 per cent DDT in a Triton-xylene-water emulsion to be applied to interior surfaces of homes and privies at the approximate rate of 200 mgms of DDT per square foot (Anonymous 1947; Quarterman 1948). In many areas two applications were made per season though a trend developed toward a single annual treatment. The spray was applied by 2- or 3-man crews operating from light trucks which also carried DDT concentrate or mixed emulsion, sprayers, and sometimes airtanks and compressors. In areas where houses were close together, power sprayers were often used. Crews were trained to follow a definite pattern in spraying; emulsion strengths were adjusted and nozzles were calibrated in advance to insure proper and uniform spray coverage (Tetzlaff 1949).

The county was the usual unit of operation and most projects were county-wide excluding communities of 2500 or more. The preapproval of counties, originally based upon an average annual reported malaria death rate of 10 per 100,000 from 1938 to 1942, inclusive, was reduced in 1947 to 5 per 100,000. As malaria mortality was virtually eliminated in many of the counties, it later became desirable to adjust the criteria so that spraying in 1949 and thereafter was done only in (1) counties with a 5 per 100,000 malaria death rate as above, provided they also had an average reported malaria death rate of 1 or more per 100,000 from 1943–46, inclusive, (2) counties with a rate of 4 or more per 100,000 for this same period irrespective of their previous mortality experience, and (3) rural homes within one mile of malaria cases confirmed in the State health department laboratories (Bradley and Lyman 1949).

Efforts were made to encourage the domestic use of space- and residual-type insecticides by the general public. The specific reductive effect of these materials against anophelines most likely to be concerned in the transmission of malaria has been well demonstrated in other countries (Andrews 1950).

Figure 1 shows the geographic extent of the DDT spray operations during 1948, the year of greatest coverage. It is virtually the map of residual endemicity. Material and man-hour data are shown in Table I by year, together with the numbers of spray applications. The latter are graphed in Figure 2 in relation to total costs by years divided according to federal and State-local contributions. The sum of these from fiscal year 1947 through 1950 amounts to roughly $18,000,000. It has not been possible to maintain federal funds at the level hoped; indeed, there have been reductions each year since fiscal 1948. The balance of the costs has been assumed by State and local agencies. This voluntary partnership to solve a health problem with peculiarly local aspects and yet of inter-state and national and even international significance is of historic interest.

The insecticidal operations were evaluated by the entomologists who made afternoon searches for *Anopheles quadrimaculatus* in random samples of sprayed buildings at various intervals after DDT was applied and of unsprayed but otherwise comparable structures (Bradley and Lyman 1950). Figure 3, based on five years' ob-

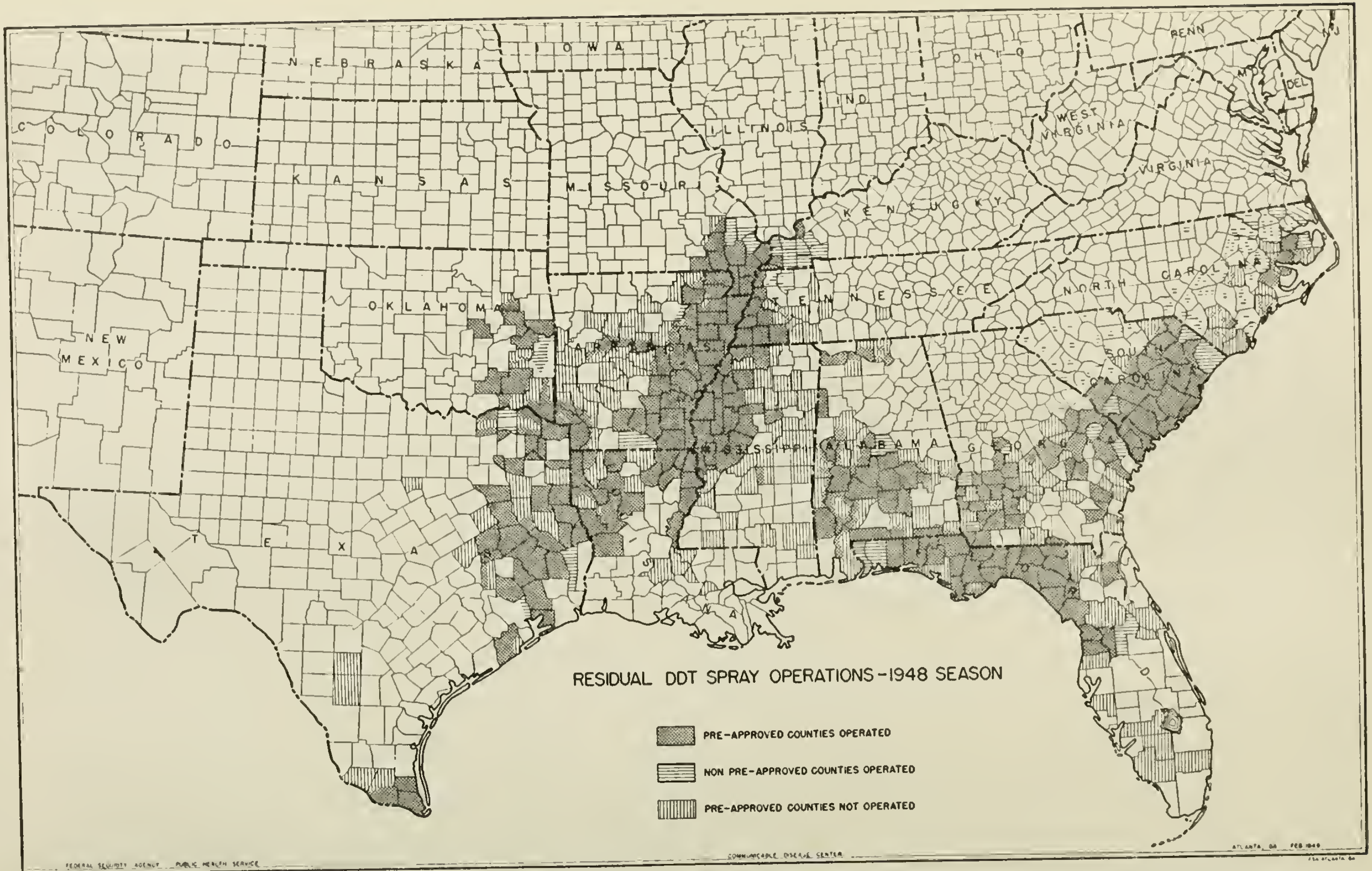

FIG. 1. Extent of residual DDT spray operations during 1948 season of the National Malaria Eradication Program (after Tetzlaff, 1949).

servations, shows that virtually all treated houses remained free from *A. quadrimaculatus* for at least five months after spraying, whereas this species was found in 16 per cent of the unsprayed houses.

TABLE I

Extended and national malaria eradication program residual house spraying operations

FISCAL YEAR	NO. OF STATES	NO. OF COUNTIES	NO. OF SPRAY APPLICATIONS	POUNDS DDT	POUNDS DDT PER APPLICATION	MAN-HOURS PER APPLICATION
1945	13	112	260,563	109,092	0.43	1.35
1946	13	274	1,025,402	709,140	0.69	1.05
1947	13	315	1,278,509	991,938	0.78	1.32
1948	13	360	1,363,799	1,405,813	1.03	1.36
1949	13	361	1,055,503	1,262,283	1.20	1.50
1950	13	332	842,509	946,386	1.12	1.27

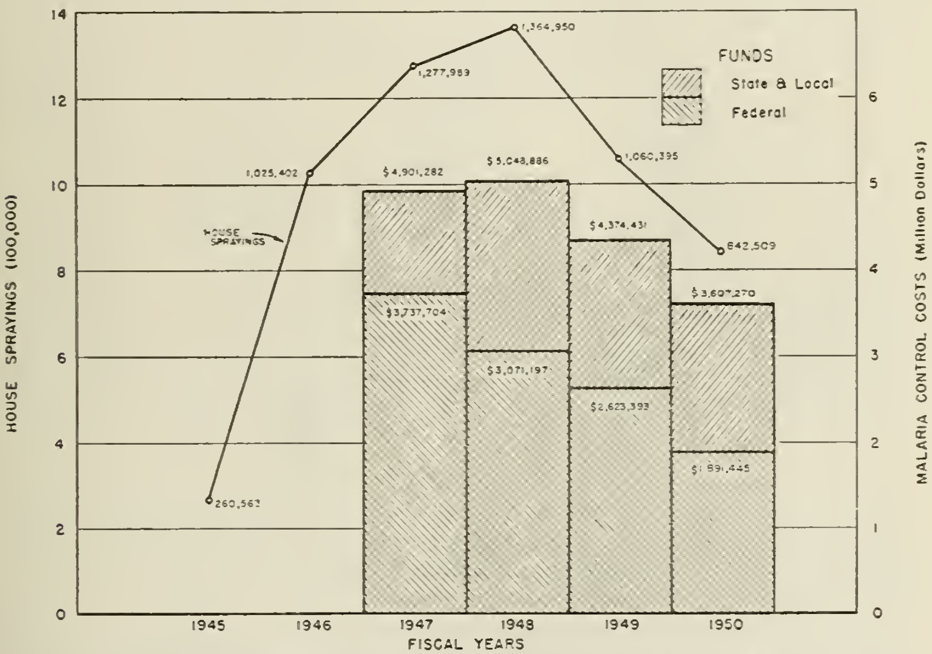

FIG. 2. U. S. Public Health Service—State Health Department National Malaria Eradication Program (13 southern States), 1945–50.

In order to detect as early as possible any evidence of malaria resurgence where it was most likely to reappear, three Malaria Observation Stations were established. Two are located in areas representative of physiographic regions formerly associated with high levels of endemicity. One of these is the east gulf coastal plain with its underlying substrate of limestone and its surface punctured by numerous "limesinks", in many of which vectoral anophelines are produced. The other is the alluvial plains of the Mississippi Delta, long noted for their intense malariousness. The third

station is near a large, inadequately-cleared artificial impoundment of the type which has been traditionally associated with malariogenicity in this country.

The activities at these installations include the current evaluation of the malaria potential, and regular observation and analysis of factors which might be concerned in the extension and recession of the disease. Although station objectives are essentially similar, the actual programs have varied according to local conditions and interest in cognate investigations (Bradley and Goodwin 1949). They are staffed primarily with malaria biologists and their satellite technicians. Two of them have been operated cooperatively with State health departments; the third in conjunction

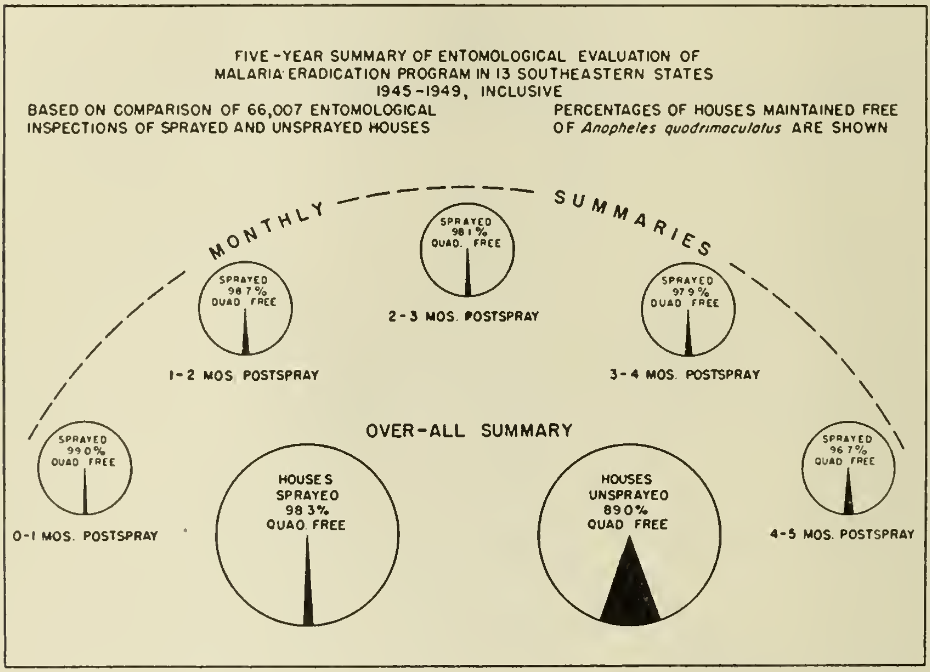

FIG. 3. Five-year Summary of Entomological Evaluation of Malaria Eradication in 13 Southeastern States, 1945–1949, inclusive. (Data from Bradley and Lyman, 1950)

with a university medical school. No evidence of renascent malaria has been elicited thus far from any of the three station areas.

The need for better epidemiologic intelligence concerning malaria prevalence as a guide to economic and effective operations and as the final tool for their evaluation became increasingly critical with the progress of the program. The low levels of transmission made spleen and parasite surveys unproductive methods of malariometry. Though their trends are known to reflect major changes in seasonal and geographic incidence (Andrews 1941), physicians' reports of malaria cases and deaths have been generally found to be unreliable sources of information (Quinby 1951), but no others were available. Of the two, certified malaria mortality has been considered in the past to be the more dependable, but its potential utility faded with

the advent of more efficient antimalarial drugs. Accordingly, efforts were made and are still underway to improve the quality of this reportorial information, especially the notification of cases. Refresher courses in the recognition and identification of malaria parasites were offered by the Communicable Disease Center in Atlanta, Georgia (Anonymous 1948–50b). These have been attended by more than 350 technicians and supervisors in laboratories, principally State health department and Veterans hospital, from all but one State in the country. A reference diagnostic service to which problem specimens may be sent is maintained by the Center. It was hoped by these means to improve the quality of the laboratory facilities available to practitioners for the diagnosis of malaria.

Public Health Service medical and nurse officers were provided to the limit of their availability, to supplement the epidemiologic facilities of certain State health departments.* This personnel investigated and tried to verify cases and deaths claimed to be due to malaria. Where possible, they assisted practitioners in making differential diagnoses of questionable cases. They supplied information about the new malaria drugs. Better reporting by physicians was promoted by explaining how this information was utilized. Though the situation is still far from ideal, very real improvements accrued from these activities. They have become the basis of the surveillance-and-prevention phase of the eradication program.

This last is just getting underway. It is hoped that Federal funds will make available trained epidemiologists, medical or nurse, together with entomologists, engineers, and certain items of equipment in seven of the 13 eradication States during the fiscal year 1951; the other States should be similarly supplied during fiscal 1952. The primary purpose of these teams will be to search for unreported cases of malaria, to investigate and appraise both these and reported cases, ditto regarding deaths certified as malaria, to search for other infected individuals and vectoral mosquitoes in the environs of proved or strongly presumptive cases, and to take measures to prevent the spread of malaria from such individuals. They will also be available for similar duties with respect to murine typhus, fly-borne diarrhea, and other communicable diseases in which the States and the Communicable Disease Center have vested interests.

The length of time that these measures should or can be continued is unknown. Assuming the complete extinction of endemic malaria from this country, the remaining sources of infection from which transmission might occur are relapsing and imported cases or carriers. Relapses after three or four years of latency must be very rare, but they do occur. Imported infections may be expected to enter the country by foot, train, motor-car, airplane, or surface vessel as long as cases occur in other nations of the world. To protect completely against such eventualities would require, in theory at least, the maintenance of surveillance and prevention (1) until all the infected persons within or who enter the United States are radically cured, die, or leave the country, and (2) until malaria is eradicated from the rest of the world. Such prolonged provision would hardly be supportable in fact, and is probably not necessary. The present plan is to see that the health departments of the traditionally

* Six States (Alabama, Arkansas, Georgia, Mississippi, South Carolina, and Texas) have been thus assisted.

malarious States are augmented as indicated above as soon as possible within the limitations of available funds and man-power. Together with the malaria observation stations and the continuance of technical development in this field, the federal cost will run about a half-million dollars per year. It is hoped that special surveillance-and-prevention personnel may be kept in States until the criteria for the cessation of malaria endemicity recommended by the National Malaria Society are fulfilled. From there on, it is expected that the States will continue the activities, which should be minimal except in Texas (due to the special problem of malaria importation from Mexico) calling upon federal assistance if endemic malaria becomes reestablished and threatens to spread to other States.

So much for the National Malaria Eradication Program. What is the present status of malaria prevalence in the country? This consideration has been the subject of several reports (Andrews and Quinby 1950; Andrews *et al.* 1950) which are briefly summarized here. Three types of information are available: (1) reported malaria mortality and morbidity, (2) blood examinations for malaria parasites made in State and Federal Health laboratories, and (3) malaria appraisal findings obtained from State epidemiologists and their assistants furnished by the Communicable Disease Center.

Reported malaria deaths and cases for the Nation since 1932 are shown in Figure 4. Similar data are avilable for each of the thirteen eradication States and are displayed graphically in Figures 7 to 19 inclusive. The mortality curves of all of them slope downward; but it is evident from examination of "malaria" death certificates that their numbers are spuriously high, that the trends of these curves should indicate more rapid descents, and that the present level of malaria mortality should be at or very near zero. There is no reason for deaths caused by malaria in this country and they probably do not occur except rarely among immigrants with neglected and overwhelming infections.

Malaria morbidity statistics are also grossly inaccurate, but the weight of error has shifted during the last 10 or 15 years from under- to over-reporting. During the thirties, malaria was epidemic in much of the South as is shown in the national and State graphs. At that time parasite rates up to 50 per cent in children were not uncommon in the rural sections of many counties (Editorial 1938; Williams 1935) though related levels of malaria illness were not being reported. During recent years, however, as will be shown below, the situation has changed so that it is now evident that the number of cases reported greatly exceeds the demonstrable prevalence. The morbidity curve in Figure 4 and those in the State graphs are subject to this distortion plus, in some instances, another of a purely statistical nature. This was caused by changes from unidentified group case reporting to notification by name and address of patients in Mississippi and South Carolina in 1947 and 1949, respectively. These States had been heavy contributors of malaria morbidity statistics prior to the change, but the numbers of cases reported thereafter were drastically reduced in comparison (see Figures 13 and 17). Whether or not these modernizations have prevented the reporting of actual cases of malaria is not known, but the results of case-appraisal and case-finding activities in these two States suggest that this is not the case. Texas remains the only State whose morbidity report-

ing system does not identify the patient. In 1949, the Lone Star State reported two-thirds of the alleged malaria morbidity of the nation!

The morbidity curve in Figure 4 shows a generally progressive decline interrupted in the mid-forties by a slight bulge and apparently accelerated since 1947. We would like to claim this last as the natural consequence of intensified malaria control activities, but it is quite obviously due to the reportorial changes in Mississippi and South Carolina mentioned above plus the deletion by States of obviously spurious reports based on appraisal findings. The increased case numbers from 1943 to 1948

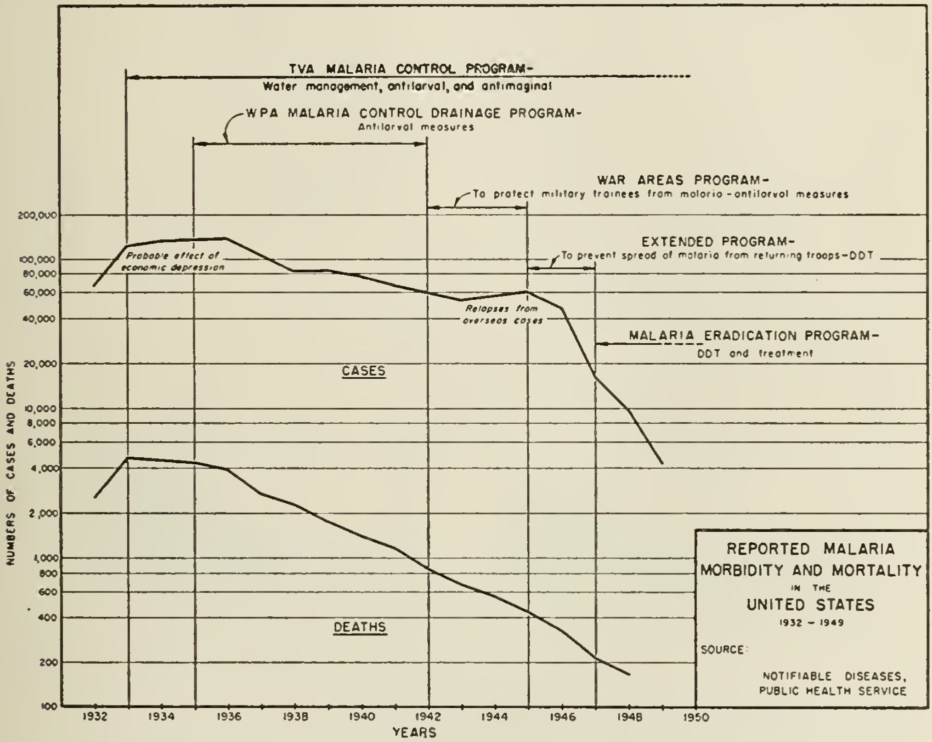

FIG. 4. Reported Malaria Morbidity and Mortality in the United States, 1932–49.

represent the relapses experienced by repatriated service personnel infected overseas. This effect is clearly evident in most of the State graphs and is analyzed in terms of absolute and proportional magnitudes for the 13 eradication states versus the rest of the Nation in Figure 5. It is probable that only small fractions of the actual number of imported relapses are recorded in these graphs (Andrews *et al.* 1950). They show that numerically the epidemic of the mid-thirties was a much more significant malariologic episode in the South than the spate of imported reactivations in the mid-forties, and the latter produced a proportionately higher crest in the non-malarious than in the eradication States.

It may be fairly concluded from these reported malaria statistics that the incidence of indigenous malaria has diminished continuously since the epidemic wave in the

mid-thirties; but, because of their fallibility, we cannot learn from them how close we are to the extinction of endemic malaria in this country.

During the last 18 years, some three million examinations of blood for malaria parasites have been made in State and Federal laboratories. An analysis of the results provides an interesting and probably very authentic confirmation (Andrews and Quinby 1950; Andrews *et al.* 1950) of the recession indicated by the reported statistics. The films were about equally divided between those collected for routine diagnostic service requested by practicing physicians and for survey purposes to measure the endemicity of malaria. These are summarized for the Nation in Figure 6 and by States in Figures 7 to 19, inclusive. Considerable numbers of specimens were

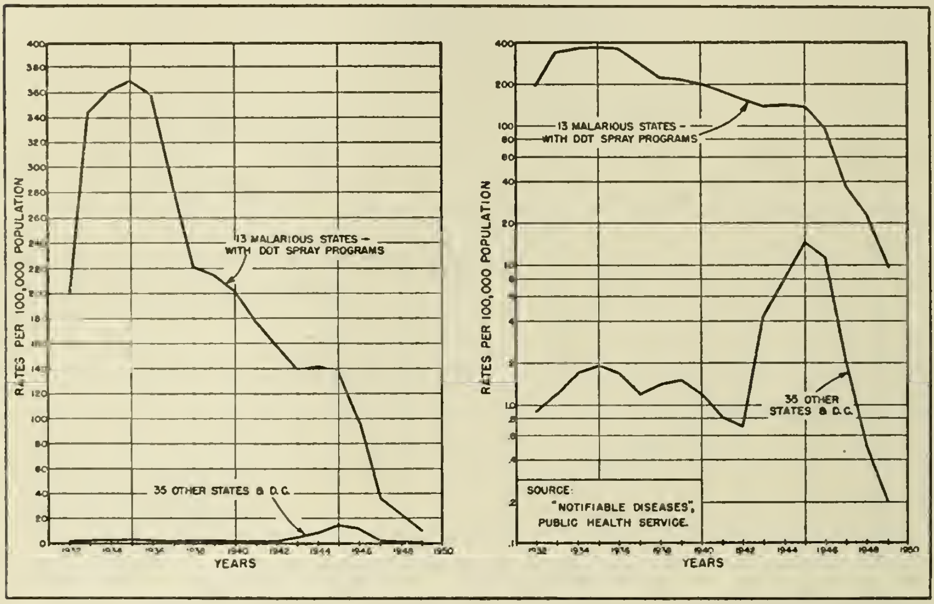

FIG. 5. Reported Malaria Morbidity from States Sprayed During Extended Malaria Control and Malaria Eradication Programs vs. Unsprayed States, 1932–49.

examined each year. The most striking feature of these graphs is the marked decline in the percentages of slides positive. The diagnostic curve, peaking in 1946, shows the effect of relapsing malaria during and after demobilization. The 1944 increase in the percentages of positive survey slides gives evidence of the latest local epidemic in the country; this occurred near the Santee-Cooper impoundment in South Carolina. Since 1945, surveys have been made there at monthly intervals, but the proportion of positive findings has subsided. It is of interest to note that the physician demand for diagnostic service from laboratories, as tokened by the numbers of diagnostic slides examined each year, has decreased markedly and consistently since 1939, suggesting that fewer and fewer patients were suspected of having malaria. The two spikes in the right-hand curve of slides examined indicate the amplitude of two extensive surveys made throughout the South (Boyd and Kitchen 1937). The percentage of positive findings in the 1934 survey was 6.1; in

the 1942 survey, 0.3. Thus the laboratory data concur with the reported statistics in recording the steady dissolution of paludism in this country.

The systematic appraisal of malaria cases started in 1947. During the first two years the number of reported cases was so large and the number of investigators so small that attention was directed to the few physicians in each area who reported the majority of cases and deaths. Efforts to confirm their allegations were rarely successful and it was concluded that these practitioners were not seeing any more malaria than the other doctors in the same area who reported fewer cases.

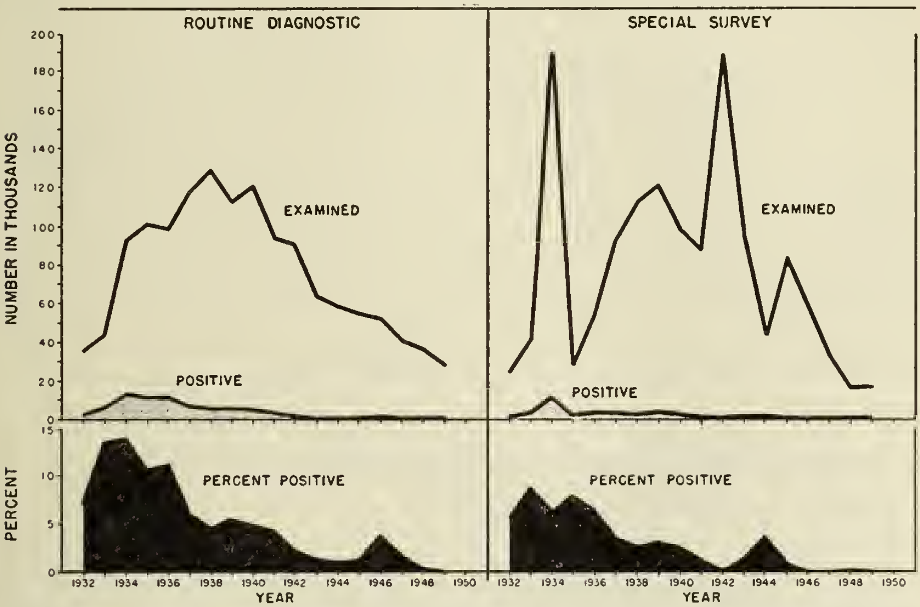

FIG. 6. Blood Examinations for Malaria Parasites made in the 13 Eradication States by State and Federal Laboratories, 1932–49.

In 1949, emphasis was shifted from contacting these physicians to appraising individual cases and deaths claimed to be due to malaria. Most of these were reported, but some previously unreported cases were discovered by following up various leads. As many as possible of these were investigated to obtain information of epidemiologic significance, the primary objective being to determine if the episode was actually malaria and, if so, when and where it was contracted. Items of especial significance were the history of malaria attacks, of trips to other countries where malaria was endemic, of recent blood transfusion, and of treatment with antimalarials. These records were reviewed by the State epidemiologists who appraised them as to confirmation, probable source and time of infection. In evaluating the former, principal reliance was placed on acceptable evidence of blood parasitism, i.e., positive reports from laboratories approved by State health departments. This may be considered an unnecessarily exclusive criterion of infection, but it remains the most objective test available and one which has high correlation with symptoms in laboratories where induced malaria is being studied (Boyd and Kitchen 1937; Eyles and Young 1948).

Table II summarizes the results of case appraisal available thus far (Quinby 1951; Quinby and Welch 1951) in relation to cases reported.* It will be noted that relatively small fractions of the numbers of cases appraised were found parasite-positive, and that only 19 in 1949 and 7 in 1950 were considered indigenous primary attacks by State epidemiologists. This means that they were not adequately explained as being relapses, transfusions, or imported cases. Actually many of the 19 and 7 cases so classified occurred under epidemiologic circumstances which suggest, though they do not prove, that they are neither primary nor indigenous, each of them having the unusual characteristic of occurring sporadically and without clear relation to other

TABLE II

Appraisal of malaria cases reported or discovered in 13 eradication states

MALARIA CASES	1948	1949	1950 THROUGH SEPTEMBER
Reported	9317	4012	1819
Appraised	770	381	586
Positive*	242†	65	26
Primary*		19	7
Relapses	UNDETERMINED	9	7
Introduced		29	11
Transfusion		2	1
Induced		1	0
Source Unknown		5	0

* By year of attack for indigenous cases; by year of appraisal for introduced cases.

† In addition to parasite-positive cases, includes "presumptives", i.e., with consistent clinical histories but not confirmed by approved laboratories.

cases. Uncontested instances of primary malaria are so infrequent and unrelated that the occurrence of serial transmission seems extremely improbable unless one postulates the existence of numerous, asymptomatic carriers which have not been revealed thus far by surveys. The question can be answered only by securing more critical diagnosis, reporting, and appraisal of cases. This is considered the strongest evidence thus far available that transmission has either ceased completely or is maintained at very low levels in isolated areas.

From the above it may be reasonably concluded that a careful review of the reported statistics of malaria mortality and morbidity, of routine diagnostic and survey blood examinations, and of case appraisals supports the contention that our endemic malaria has declined to a very low level. It is probably approaching the vanishing point. But this information is not comprehensive enough to prove that malaria has been eradicated in this country. As long as parasite-positive cases which cannot be adequately explained except as primary indigenous infections are found each year, it must be conceded that the battle is not yet won.

The final question to be considered is the actual role, if any, of the National Malaria Eradication Program in reducing malaria to the hypo- or non-endemic status. Prevalence was diminishing when the program commenced. Conventional malario-

* The failure of case numbers in Table II to agree with those in the references is due to additional available data since these papers were published.

metric procedures are not accurate enough to detect or exclude evidence of accelerated decline after the eradication activities were launched. It is improbable that all homes in areas of recent endemicity were treated with DDT. The same antimalarial factors which were believed to be operating before the program started (Andrews 1948b) were still in effect and may have been augumented or intensified during its progress. Would malaria incidence have continued to decline and would it have descended to its present level if this program had not been activated?

The author believes that there is no direct and unequivocal answer to this question, at least for the present. In the interests of prudent preventive medical practice and because this was an eradicative project, no comparison areas were left without treatment. Thus it is not possible to gauge program effectiveness on a truly comparative basis. Even if this were the case, it must be remembered that medicine has made mighty advances in therapeutic knowledge during recent years. To a large extent, sulpha drugs and antibiotics must have replaced quinine in the treatment of febrile disorders which were previously recorded as malaria. We are still plagued in this country, as our case appraisal data reveal, by casual but unsupported diagnoses of malaria. The use of insecticides, screening, or drainage will not reduce the incidence of spurious paludism, but careful and persistent epidemiologic investigation will generate increasing pressure on physicians to differentiate more carefully between malarial and non-malarial fevers, to the numerical reduction of the former. Presumably this might occur as readily in areas where antimalarial activities are not being practiced as in others.

On the other hand, the principles and practices applied in this program have been those which operated with dramatic effectiveness in other parts of the world where background incidence was higher and was not diminishing. They have been aimed squarely at the heart of the malaria problem in this country. Their success in reducing the numbers of anophelines in houses, the touchstone to the prevention of malaria carried by house-resting vectors, has been attested entomologically. The expected epidemic due to transmission from cases of imported malaria has failed to manifest itself though it is known that upwards of 100,000 relapses, the actual number is not known but there were probably several times as many, have occurred in service and veteran personnel returned to their homes (Simmons 1948). In view of our present knowledge of proved malaria incidence in this country, this number was undoubtedly as large or greater than that of infected persons then resident in the United States. It is hard to imagine that the relatively sudden and tremendous enhancement of sources of infection could have been unattended by significant outbreaks of malaria unless some nullifying influences were at work.

Admitting the existence of other antagonistic factors, there can be little doubt that the reduction of *bona fide* primary malaria in this country during the last twenty years is due in large part to the use of insecticides in the home. Much of this has been accomplished by their occupants and owners, but to the extent, and this is not unsubstantial and may even be *sine qua non*, that government-sponsored antimalarial programs have encrusted with DDT the interior surfaces of homes where malaria was most likely to occur and where insecticides or screening were least likely to be used, these activities must have contributed significantly to our national malaria recession.

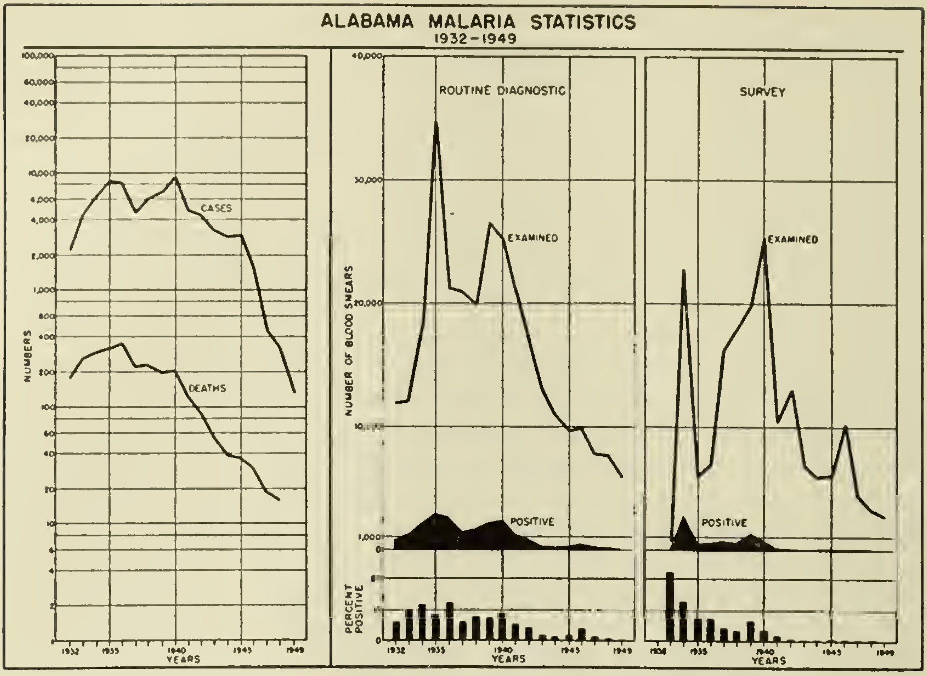

FIG. 7. Morbidity-Mortality and Routine Diagnostic Laboratory and Survey Malaria Statistics for Alabama, 1932–49.

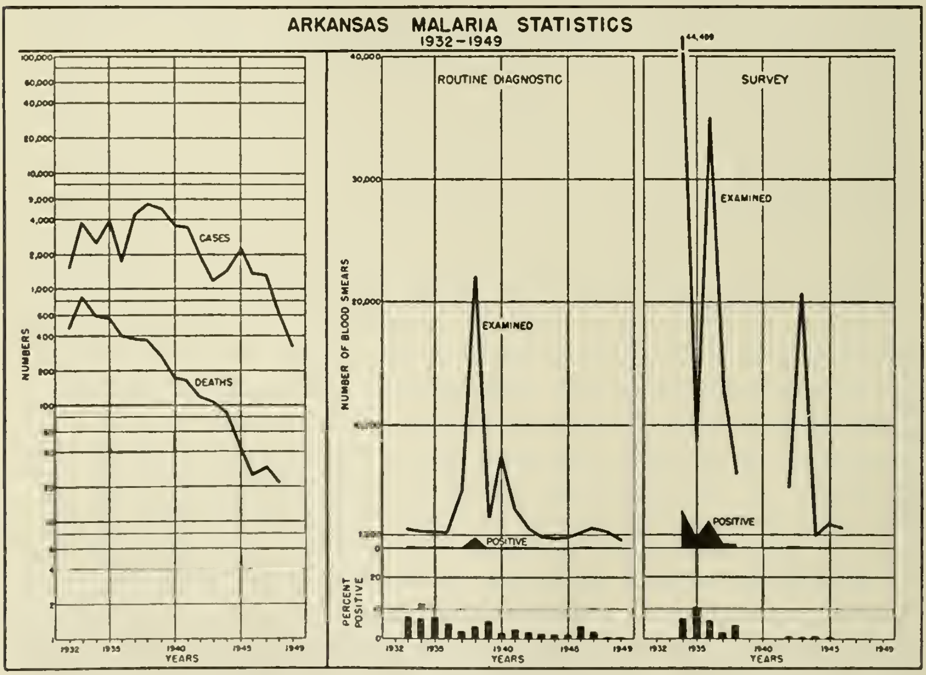

FIG. 8. Morbidity-Mortality and Routine Diagnostic Laboratory and Survey Malaria Statistics for Arkansas, 1932–49.

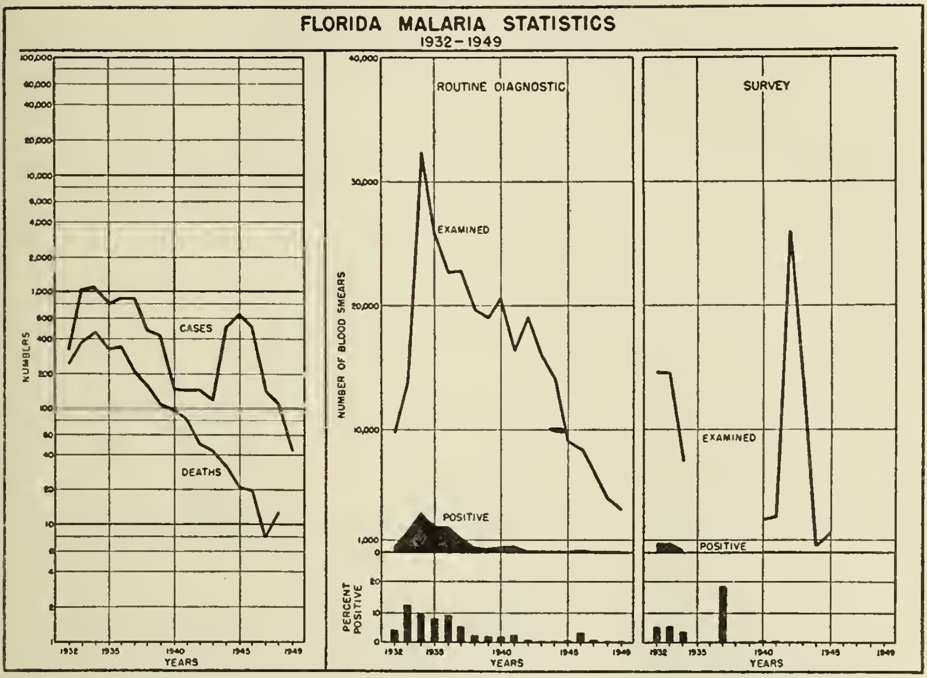

FIG. 9. Morbidity-Mortality and Routine Diagnostic Laboratory and Survey Malaria Statistics for Florida, 1932–49.

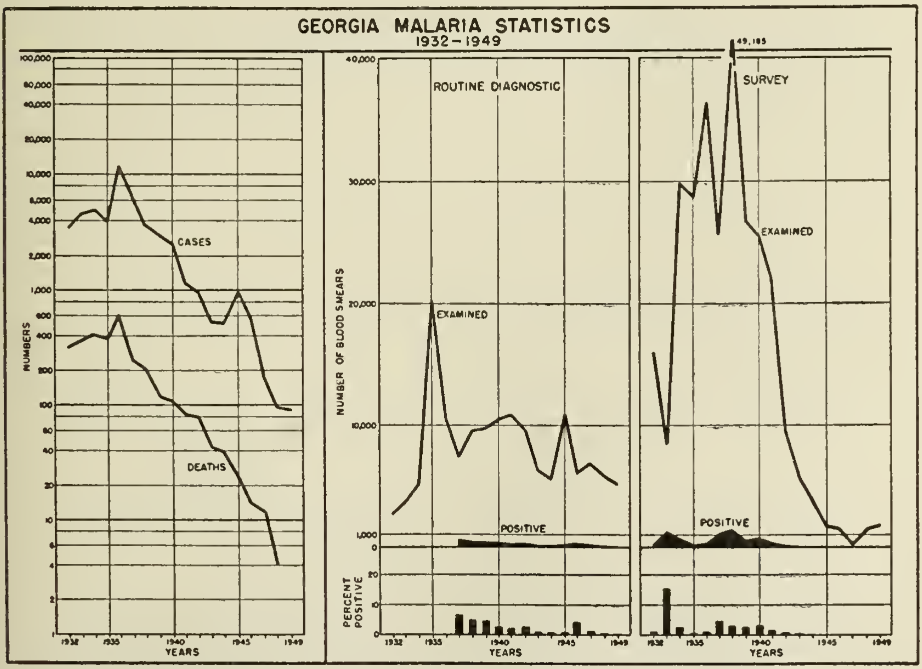

FIG. 10. Morbidity-Mortality and Routine Diagnostic Laboratory and Survey Malaria Statistics for Georgia, 1932–49.

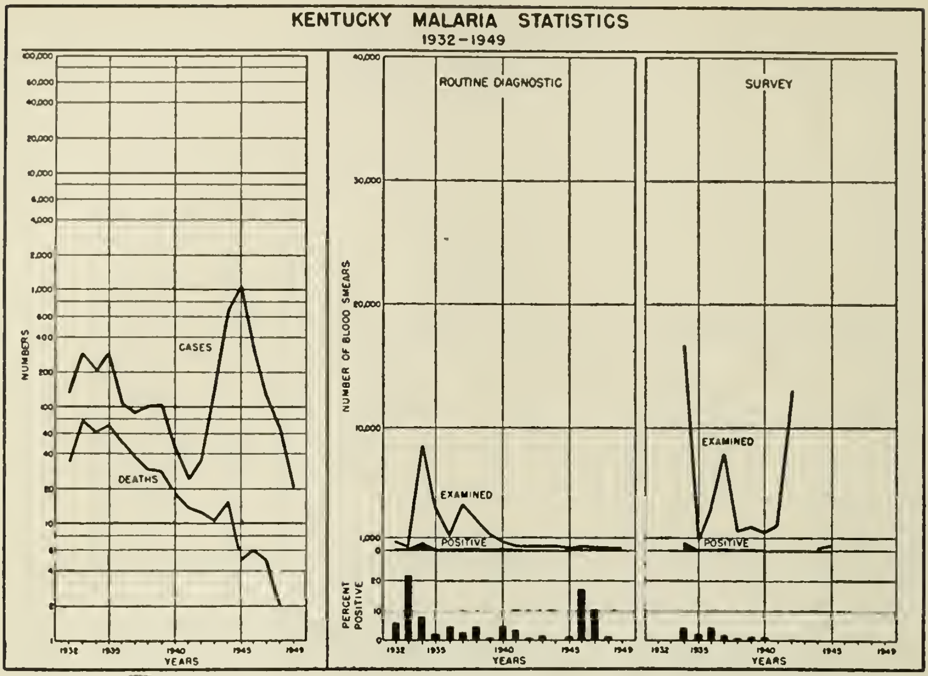

FIG. 11. Morbidity-Mortality and Routine Diagnostic Laboratory and Survey Malaria Statistics for Kentucky, 1932–49.

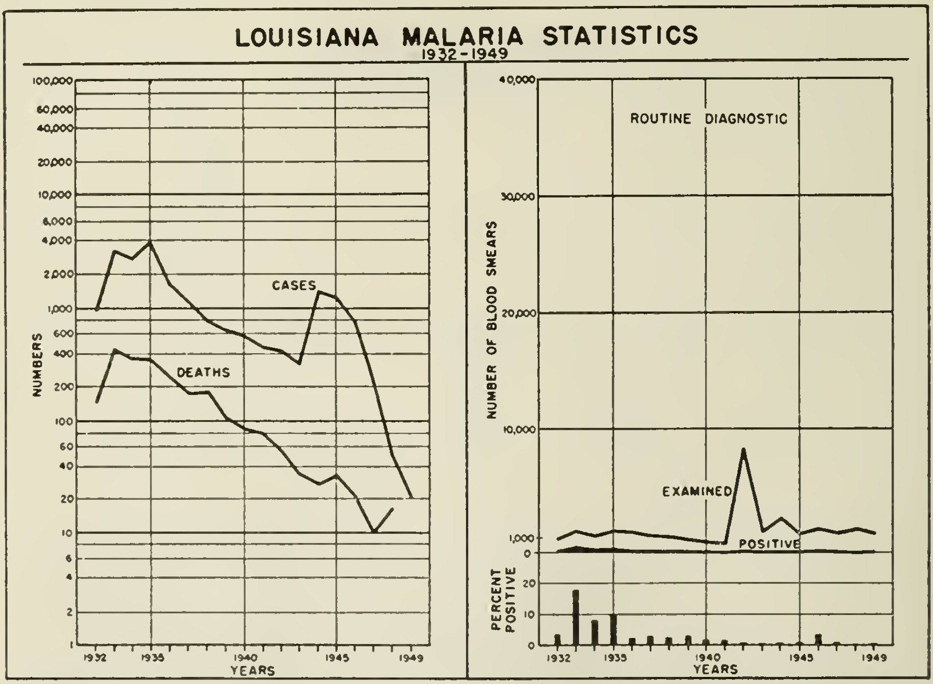

FIG. 12. Morbidity-Mortality and Routine Diagnostic Laboratory Malaria Statistics for Louisiana, 1932–49.

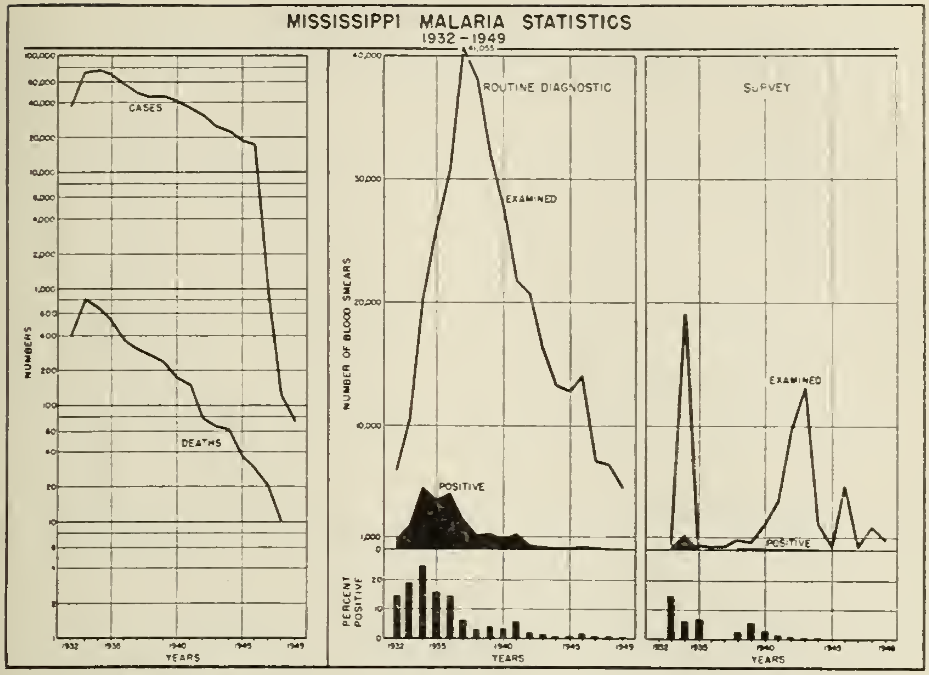

Fig. 13. Morbidity-Mortality and Routine Diagnostic Laboratory and Survey Malaria Statistics for Mississippi, 1932–49.

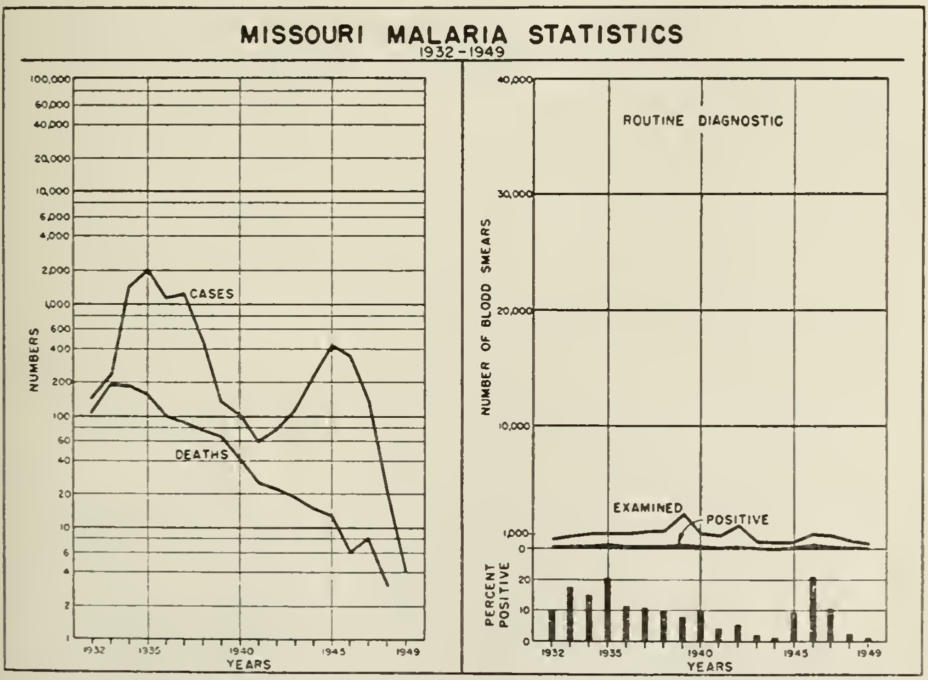

Fig. 14. Morbidity-Mortality and Routine Diagnostic Laboratory Malaria Statistics for Missouri, 1932–49.

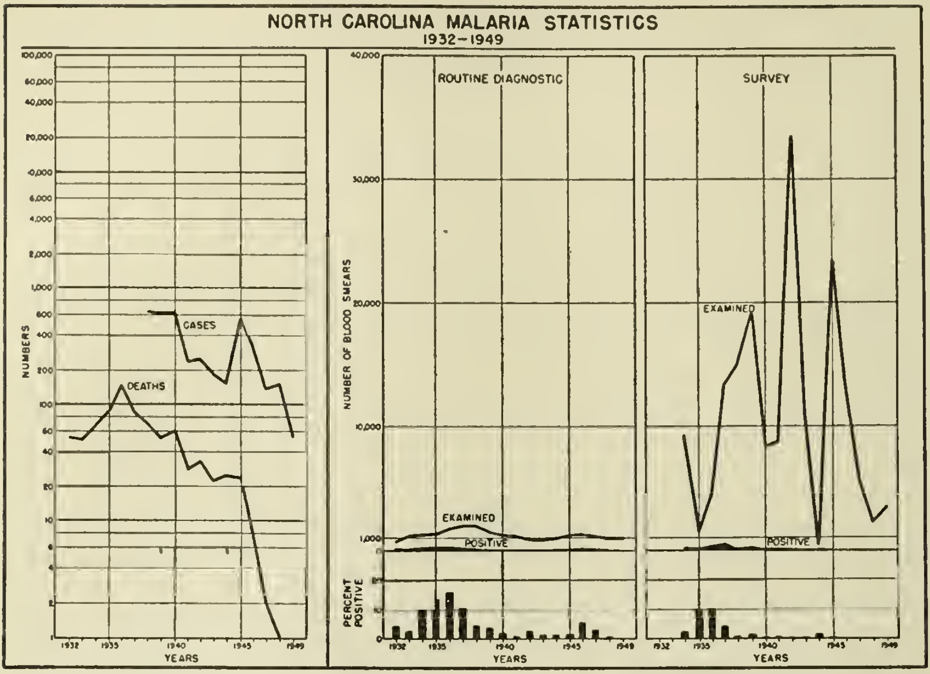

FIG. 15. Morbidity-Mortality and Routine Diagnostic Laboratory and Survey Malaria Statistics for North Carolina, 1932–49.

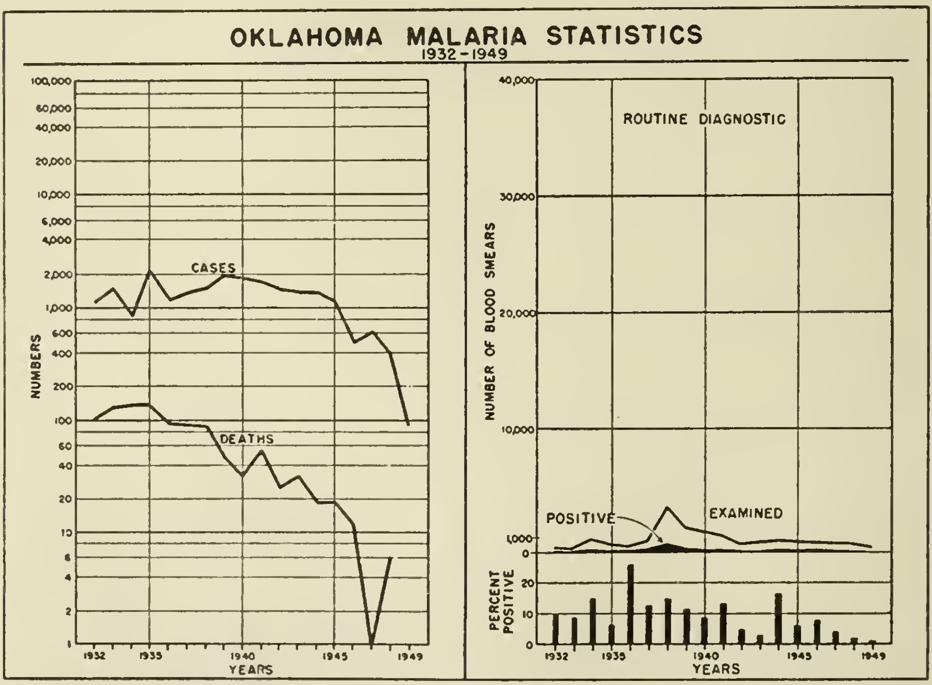

FIG. 16. Morbidity-Mortality and Routine Diagnostic Laboratory Malaria Statistics for Oklahoma, 1932–49.

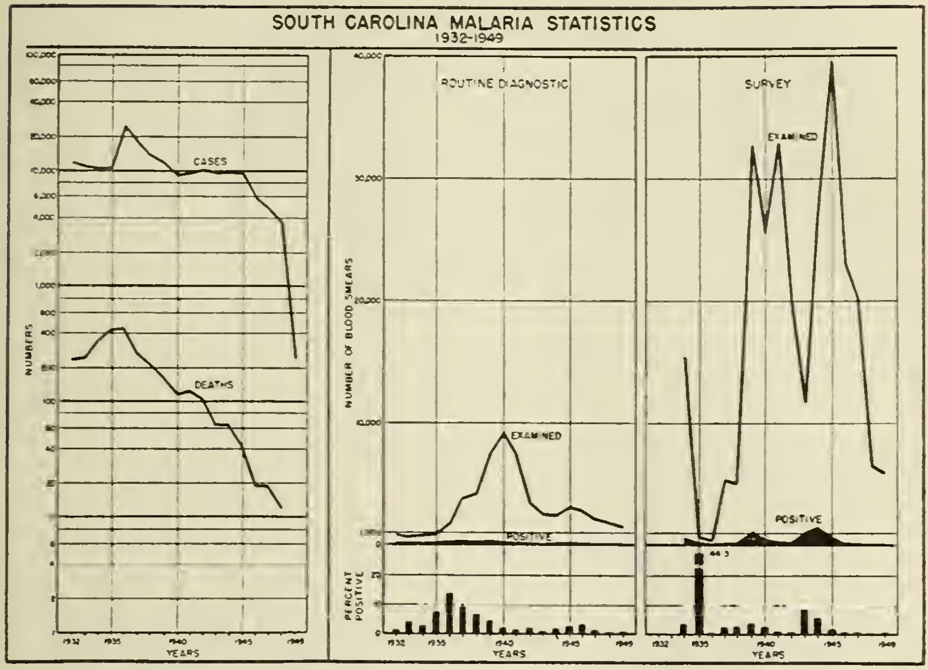

Fig. 17. Morbidity-Mortality and Routine Diagnostic Laboratory and Survey Malaria Statistics for South Carolina, 1932–49.

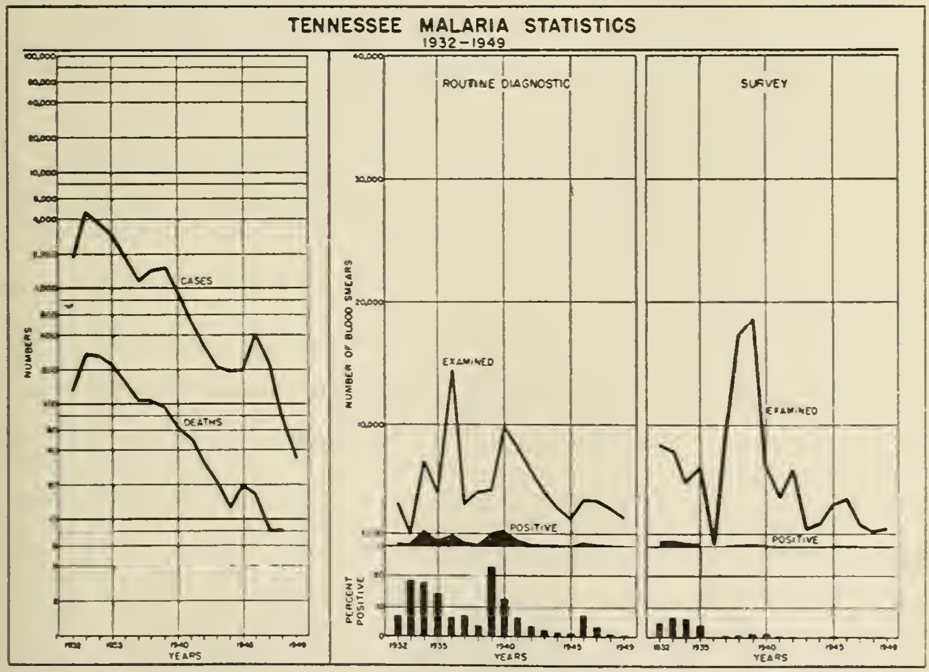

Fig. 18. Morbidity-Mortality and Routine Diagnostic Laboratory and Survey Malaria Statistics for Tennessee, 1932–49.

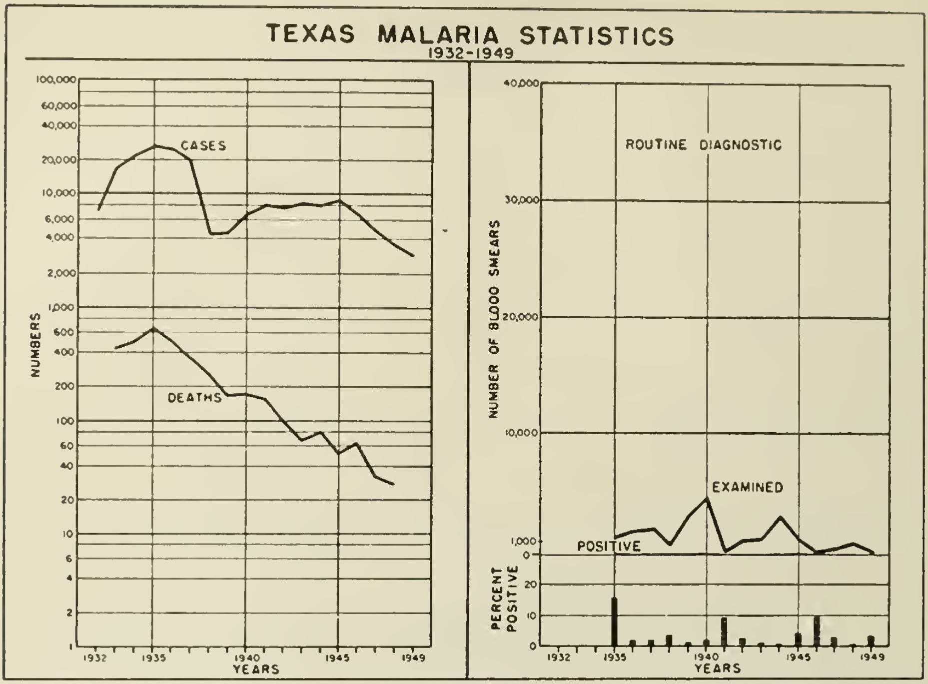

FIG. 19. Morbidity-Mortality and Routine Diagnostic Laboratory Malaria Statistics for Texas, 1932–49.

REFERENCES

ACKERKNECHT, E. H. 1945. Malaria in the Upper Mississippi Valley, 1760–1900. Supp. Bull., History of Medicine. Baltimore: Johns Hopkins Press. 142 pp.

ANONYMOUS. 1948–1950a. Bulletins of Field Training Programs. Training in Insect and Rodent Control. F. S. A. Public Health Service, Communicable Disease Center, Atlanta, Ga.

ANONYMOUS. 1948–1950b. Bulletins of Field Training Programs. Schedules for Public Health Laboratory Courses. F. S. A. Public Health Service, Communicable Disease Center, Atlanta, Ga.

ANONYMOUS. Undated. Film Catalog—Utilization Guide. F. S. A. Public Health Service, Communicable Disease Center, Atlanta, Ga.

ANONYMOUS. 1947. DDT Residual Spray Operations. Handbook. F. S. A. Public Health Service, Communicable Disease Center, Atlanta, Ga.

ANDREWS, JUSTIN M. 1941. General Considerations in Planning Malaria Control. Human Malaria. Amer. Assoc. Adv. Sci., Pub. No. 15, pp. 285–295.

ANDREWS, JUSTIN M. 1948a. Present Proportions of the Malaria Problem in the Nearctic Region. Proc. 4th Internat. Cong. Trop. Med. & Mal., **1:** 903–913.

ANDREWS, JUSTIN M. 1948b. What's Happening to Malaria in the U. S. A.? Am. Jour. Pub. Health, **38:** 931–942.

ANDREWS, JUSTIN M. AND GILBERTSON, WESLEY E. 1948. Blueprint for Malaria Eradication in the United States. Jour. Nat. Mal. Soc., **5:** 167–170.

ANDREWS, JUSTIN M. 1950. Advancing Frontiers in Insect Vector Control. Am. Jour. Pub. Health **40:** 409–417.

ANDREWS, JUSTIN M. AND QUINBY, GRIFFITH E. 1950. Current Status of Malaria Eradication in the South. Proc. South. Br., Am. Pub. Health Assoc., Birmingham, Ala. pp. 6–11.

ANDREWS, JUSTIN M., QUINBY, GRIFFITH E. AND LANGMUIR, ALEXANDER D. 1950. Malaria Eradication in the United States. Am. Jour. Pub. Health, **40:** 1405–1411.

Barber, M. A. 1929. The History of Malaria in the United States. Pub. Health Rep., **44**: 2575–2587.

Boyd, Mark F. 1941. A Historical Sketch of the Prevalence of Malaria in North America. Am. Jour. Trop. Med., **21**: 223–244.

Boyd, Mark F. and Kitchen, S. F. 1937. Observations on Induced Falciparum Malaria. Am. Jour. Trop. Med., **17**: 213–235.

Bradley, G. H. and Fritz, R. F. 1947. Entomological Evaluation of Results of Residual DDT Spraying During 1946. Jour. Nat. Mal. Soc., **6**: 117–121.

Bradley, George H. and Goodwin, Melvin H., Jr. 1949. Malaria Observation Stations of the Public Health Service. Jour. Nat. Mal. Soc., **8**: 181–191.

Bradley, George H. and Lyman, F. Earle. 1949 Recent Developments in the Antimosquito Work of the Communicable Disease Center, U. S. Public Health Service. Proc. N. J. Mosq. Exterm. Assoc., **36**: 68–74.

Bradley, George H. and Lyman, F. Earle. 1950. Present Status of the Malaria Eradication Program. Proc. N. J. Mosq. Exterm. Assoc., (In press).

Editorial. 1938. Malariometry. The Georgia Malaria Bulletin **1**: 7.

Eyles, Don E. and Young, Martin D. 1948. Studies on Imported Malarias. VII. The parasitological pattern of relapsing *Plasmodium vivax* in military patients. Jour. Nat. Mal. Soc., **7**: 23–38.

Freeborn, Stanley B. 1944a. The Eradication of Endemic Malaria. Proc. 42nd Ann. Conf. U. S. Public Health Service with the State and Territorial Health Officers.

Freeborn, Stanley B. 1944b. Problems Created by Returning Malaria Carriers. Pub. Health Rep., **59**: 357–363.

Hoffman, Frederick L. 1916. A Plea for a National Committee on the Eradication of Malaria. South. Med. Jour., **9**: 413–420.

Hoffman, Frederick L. 1917. A Plea and a Plan for the Eradication of Malaria. South. Med. Jour., **10**: 309–311.

Mountin, J. W. 1944. A Program for the Eradication of Malaria from Continental United States. Jour. Nat. Mal. Soc., **3**: 69–73.

Quarterman, Kenneth D. 1948. Some Factors Influencing the Residual Effectiveness of DDT and Chlordane in Anopheline Mosquito Control. Jour. Nat. Mal. Soc., **7**: 300–306.

Quinby, Griffith E. 1951. Progress Report of Epidemiological Appraisal of Reported Cases of Malaria in the United States. (In press).

Quinby, Griffith E. and Welch, Sara F. 1951. Progress Report of Epidemiological Appraisal of Reported Malaria in the United States during 1949 and 1950. (In press).

Simmons, James S. 1948. The Malaria Control Program of the United States Army During World War II. Proc. 4th Internat. Cong. Trop. Med. & Mal., **1**: 827–940.

Soper, F. L. and Wilson, D. B. 1942. Species Eradication; a Practical Goal of Species Reduction in the Control of Mosquito-borne Disease. Jour. Nat. Mal. Soc., **1**: 5–24.

Tetzlaff, Frank. 1949. Malaria Control Progress and Problems. Jour. Nat. Mal. Soc., **8**: 115–120.

Williams, L. L., Jr. 1935. Civil Works Emergency Relief Administration Malaria Control Program in the South. Am. Jour. Pub. Health, **25**: 11.

Williams, L. L., Jr. 1938. Economic Importance of Malaria Control. Proc. N. J. Mosq. Exterm. Assoc., **25**: 148–152.

Williams, L. L., Jr. 1941. The Anti-malaria Program in North America. Human Malaria. Amer. Assoc. Adv. Sci., Pub. No. 15, pp. 365–371.

Young, Martin D., Eyles, Don E. and Burgess, Robert W. 1948. Studies on Imported Malarias. X. An evaluation of the foreign malarias introduced into the United States by returning troops. Jour. Nat. Mal. Soc., **7**: 171–185.

RESUMEN

Desde 1875 aproximadamente la preponderancia de malaria en los Estados Unidos se ha desviado del norte y el oeste atrincherándose en el cuadrante sudeste

donde hasta recientemente ha sido causa importante de inhabilidad e improductividad.

Allá para 1916 sugerencias para la exterminación de esta costosa enfermedad se habían ofrecido pero fué el concepto del Dr. L. L. Williams, Hijo, el que formó la base de la proposición de la Sociedad de Malaria Nacional que se activara un programa de exterminación de malaria.

La Oficina de Control de Malaria en Áreas de Guerra se estableció en 1942 para asistir a los estados en la reducción del peligro de malaria a estudiantes y trabajadores en áreas de importancia militar. Para 1944 mucho personal de servicio estaba retornando de ultramar trayendo consigo cepas de malaria que podían ser transmitidas por anofelinos nativos. En 1945 se hizo DDT disponible al Servicio de Salud Pública especialmente para evitar esta transmisión. Este Programa Extensivo de Control de Malaria se llevó a cabo por dos años.

De este modo todo estaba listo y en Julio 1, 1947, el Servicio de Salud Pública inició el Programa Nacional de Exterminación de Malaria con la cooperación de los trece estados interesados.* Éste se baso en dos principios, la destrucción de la endemicidad y la prevención de su reestablecimiento. El primero había de efectuarse fomentando mejor diagnosis y tratamiento de casos y reduciendo la densidad de anofelinos en las casas con insecticidas residuales; el segundo, buscando y avaluando los casos restantes e importados sospechosos. Aquellos encontrados positivos para parásitos habían de recibir tratamiento adecuado y protección de anofelinos.

Los diseños administrativos y operativos del programa dispusieron para el establecimiento federal de política extensa y general, la real administración de autoridad permaneciendo en manos del estado. El procedimiento común consistió en la aplicación de DDT al 5 porciento en una emulsion de "Triton", xileno y agua a las superficies interiores de hogares y letrinas a aproximadamente 200 mgs. de DDT por pie cuadrado una o dos veces cada estación del año. Las operaciones insecticidas fueron avaluadas por entomólogos. Estaciones de Observación de Malaria se establecieron para notar cualquier evidencia de reaparición de malaria. Para avaluar el programa de exterminación más correctamente, epidemiólogos del Servicio de Salud Pública fueron asignados a los estados para fomentar mejor reportaje de morbidez y mortalidad debido a malaria.

El progreso hacia la exterminación queda demostrado por las indicaciones siguientes: A pesar de la inexactitud en el reporte de morbidez y mortalidad de malaria, las curvas de casos de malaria y de muertes en la nación y en los trece estados de exterminación demuestran un descenso constante desde la época epidémica del treinta excepto por un ligero aumento durante el período del año cuarenta al cincuenta debido a recaídas en las tropas de servicio de ultramar. Durante los últimos diez y ocho años unos tres millones de exámenes de sangre para parásitos de malaria se han hecho en laboratorios estaduales y federales. Un análisis de los resultados demuestra decadencia en el número de especímenes para diagnosis y reconocimiento examinados y encontrados positivos, una confirmación interesante y probablemente muy auténtica del receso indicado por los datos estadísticos reportados.

* Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas.

La valuación sistemática de reportados y descubiertos casos de malaria empezó en 1947 y se ha confiado grandemente en evidencia aceptable de parasitismo sanguíneo. Fracciones relativamente bajas de los casos avaluados fueron encontrados positivos para parásitos; solamente 19 en 1949 y 7 en 1950 fueron considerados ataques indígenos primarios. Ésta se ha considerado como la evidencia disponible más fuerte de que la transmisión ha cesado completamente o existe solamente a niveles muy bajos én areas aisladas. No obstante, mientras se encuentren anualmente infecciones primarias indígenas no se ha logrado la exterminación.

El punto es discutible de si la incidencia de malaria hubiese continuado el descenso que comenzó en los últimos años del treinta hasta lograr su nivel bajo de hoy día si el Programa Nacional de Exterminación de Malaria no se hubiese activado. El autor cree que no existe una respuesta directa e inequívoca. El uso de insecticidas domésticos y medicación antipalúdica a través de los años debió haber reducido el potencial de malaria. Drogas sulfa y antibióticos han reemplazado la quinina en el tratamiento de desarreglos febriles no diagnosticados, de manera que menos casos de "malaria" han sido reportados basándose por exámenes terapéuticos. La minuciosa y persistente investigación epidemiológica ha producido creciente presión en los médicos para que éstos diferencien más cuidadosamente entre las fiebres palúdicas y las no palúdicas, resultando en una reducción del número de aquéllas. Por otra parte las prácticas y los principios aplicados en este programa han sido aquellos que operaron con efectividad dramática en otras partes del mundo donde la incidencia original era mayor y no disminuía. Probablemente la evidencia más imponente de su éxito fué la falta de un brote de malaria después del regreso a este país de personal militar infectado en el extranjero. Parece justo el concluir que debido al grado con que programas contra la malaria fomentados por el gobierno han incrustado con DDT las superficies interiores de hogares donde se encontraría malaria mayormente y donde insecticidas o protección con tela metálica se usarían mucho menos, estas actividades han debido haber contribuído significativamente al receso nacional de malaria.

NATION-WIDE MALARIA ERADICATION PROJECTS IN THE AMERICAS

DR. RUSSELL: The next speaker is a Bachelor of Philosophy and a Doctor of Medicine of the Central University of Venezuela and a Doctor of Science of Johns Hopkins University, a man who has been interested in malaria for twenty years.

Since 1936 he has been chief of the Malaria Division of the Department of Public Health in Venezuela and in this post he has not only developed the outstanding Malaria Institute in Maracay but has also planned, developed, and administered a very successful malaria eradication program which is nation-wide in scope. He has served with great distinction as chief of the Pan American Malaria Commission and as Chairman of the Expert Committee on Malaria of the Interim Commission of the World Health Organization. I do not believe I am violating any confidences when I note that he has several times refused appointment to high echelon posts within the Venezuelan Ministry of Public Health because of his intense interest in the elimination of malaria from his country.

Author of over 60 papers of scientific importance, honorary member of the American Academy of Tropical Medicine, and a member of many other professional societies, decorated by his own Government with the Order of the Liberator and also by the neighboring Government of Colombia for his notable achievements in the field of malariology, representative of his Government at several international health assemblies, this outstanding malariologist has never lost his balance but has consistently pressed forward toward his goal, patiently obtaining basic survey data, training his staff, developing his organization, and obtaining the necessary budgets. It is a real pleasure to present to you Doctor Arnoldo Gabaldon.

II. PROGRESS OF THE MALARIA CAMPAIGN IN VENEZUELA

ARNOLDO GABALDON*

Malaria used to be the most important public health problem in Venezuela. This Republic has an area of 912,050 sq. kms. (= 325,000 sq. miles) and may be divided from north to south into three regions: the Costa-Cordillera, with the coast and the Andean mountains and valleys; the Llanos, which are the flatlands extending between the foothills of the southern slope of the mountains and the Orinoco River; and the Guayana, made up of the valleys and mountains south of the Orinoco River. These three regions differ topographically, meteorologically, demographically, and economically. These variations reflect themselves in different prevalences of malaria in the three regions. In Table 1, it will be observed that the vital index was lowest in the region where the malaria mortality rate was highest. Until 1936, as the table shows, there was little consistent amelioration of the malaria problem. Since that time, notable improvement has occurred. This is due largely to the nation-wide antimalaria efforts of the Malaria Division (División de Malariología).

The Malaria Division, established in 1936, is a service unit within the Bureau of Public Health of the Ministry of Health and Social Welfare in Venezuela. It is devoted to research and training about malaria and its control. Until 1945 malaria control was based on nation-wide free drug distribution and local drainage projects in the more important centers. The large scale introduction of DDT in that year

* División de Malariología, Maracay, Aragua, Venezuela.

resulted in a spectacular reduction in malaria prevalence. The organizational structure and the results obtained in the four years of work are presented here.

ORGANIZATIONAL STRUCTURE

In 1945, when DDT first became available for civilian use, Venezuela, along with five other American republics (United States, Brazil, Columbia, Dominican Republic, and El Salvador) incorporated the use of this insecticide into its malaria control program. The work in Venezuela did not follow the classic pattern of trial on a small scale, but from the beginning was developed to cover the entire malarious zone of the country. This procedure was followed because: (a) studies carried out by the Malaria Division since 1936 had already determined the prevalence and geographic distribution of malaria and of the anopheline vectors; (b) these studies also had shown the trends of the malaria five-year and secular cycles; and (c) limited experience obtained in 1941–42 with pyrethrum and other insecticides in the control of epidemic outbreaks had indicated that *Anopheles albimanus* and *A. darlingi*, the main vectors, were susceptible to agents of interception. It was possible, there-

TABLE 1

Malaria prevalence as shown by the mortality rates in the three zones of Venezuela in relation to the population and the vital index*

REGIONS	1911–1915	1916–1920	1921–1925	1926–1930	1931–1935	1936–1940	1941–1945
Costa-Cordillera:							
Population	1,958,865	2,050,944	2,184,447	2,357,140	2,542,240	2,782,450	3,155,393
Population index	100	105	112	120	130	142	161
Malaria Mortality rate	211	253	172	140	131	75	93
Vital index	151	137	158	164	154	189	221
Llanos:							
Population	516,336	492,526	499,837	529,231	556,907	610,465	717,724
Population index	100	95	97	102	108	118	139
Malaria Mortality rate	527	653	497	418	329	323	217
Vital index	121	103	109	140	138	165	196
Guayana:							
Population	71,224	74,670	77,343	79,499	81,655	85,807	98,106
Population index	100	105	109	112	115	120	138
Malaria Mortality rate	156	151	162	172	154	110	121
Vital index	162	208	172	176	196	294	260
Venezuela:							
Population	2,546,425	2,618,140	2,761,627	2,965,870	3,180,802	3,478,722	3,971,213
Population index	100	103	108	116	125	137	157
Malaria Mortality rate	276	308	232	190	164	103	112
Vital index	145	134	150	161	152	186	218

* With exclusion of data pertaining to the two Federal Territories of Amazonas and Delta Amacuro.

fore, to make comparisons with previously collected data on the same basis instead of using control areas.

The malarious zone of Venezuela comprises any populated area, even with isolated houses, where malaria parasites and/or *A. albimanus* or *A. darlingi* have been found, and the neighboring territories with similar topography, particularly if those primary epidemiologic factors are present in these portions. This zone has an approximate area of 600,000 sq. kms., about the size of Texas. The 1949 distribution and density of housing by regions is shown in the following table:

	SQ. KMS.	HOUSES TO BE SPRAYED	HOUSES PER SQ. KMS.
Costa-Cordillera	106,000	331,875	3.1
Llanos	301,000	154,486	0.5
Guayana	193,000	21,412	0.1
Total	600,000	507,773	0.8

The difficulties involved in covering this area have been mainly (a) its extent and (b) the low density of its population. As a result of these two factors there is a lack of proper roads for motor transportation to many rural communities. This has so hampered the work that it has progressed more in extensiveness than in intensiveness. Today, all malarious places which can be reached by motor transportation have been sprayed, and at the present time we are concentrating on reducing the number of pockets which were necessarily bypassed in the original effort. These pockets may be the main factors in the reintroduction of malaria to the protected areas where it is always possible that some vectors have survived in poorly sprayed houses or in those which have remained unsprayed because of unusual circumstances.

Unfortunately there are no maps of the country which show every dwelling. Therefore, in much of the malarious zone it was necessary to survey in order to locate houses before spraying them. Nomadism in unsettled agricultural regions and the continuous appearance of new areas of exploitation make this survey activity practically endless.

CENTRAL AND FIELD SERVICES

In the Malaria Division all antivectoral activities come under the jurisdiction of the Section of Antimalaria Engineering (Sección de Ingeniería Antimalárica) in the Central Office of the Division at Maracay, Aragua. Therefore, when DDT was introduced it was the New Methods and Developments Service (Servicio de Fomento Antimalárico) in this Section which explored its possibilities for use in Venezuela. This Service formulates the general plan of action and directs and supervises the field work. The clerical office and the chemical laboratory for physico-chemical studies on DDT also are included under this Service. Other insecticide testing is done in the Special Studies Section.

The field services are administered by the zone engineers in each State or, lacking these, by the zone doctors in charge of the regional services of epidemiology and medical activities who are also regional representatives of the Division. Each zone

has one DDT Inspector who supervises the work of the squads, thoroughly explores the terrain surveying and "house hunting", and helps his chief in promoting improvements.

The squads are groups of 3 to 8 spray-men with their leader and auxiliary personnel, drivers, pilots, etc. There are different kinds of squads depending on their type of locomotion: truck, motorboat, wheelbarrow, trolley, horseback, or foot.

The men are in uniform with their grades marked on their left arms. Each man has spraying equipment for which he is accountable to the squad-leader. Each squad-leader is responsible to the zone engineer or doctor.

The trucks used are war surplus items with front-wheel drive. These are rather large and are being replaced now by smaller units of the power-wagon or weapons-carrier and jeep types which are more suitable for narrow secondary roads. In the back of the trucks are seats adapted to carry the men and their personal baggage, drums of DDT, two 500-liter tanks for suspensions, and one or two 200-liter tanks for solution. With this equipment a truck may work for about one week away from a supply base. Smaller trucks or jeeps must return more frequently. The squads using jeep transportation generally prepare suspensions only as needed and, therefore, no suspension tanks are carried in these vehicles.

The towns, small pueblos, and isolated houses on the river banks and lake shores are reached by motor-boats. These are of two types, large ones made of steel and smaller wooden ones with outboard motors. The larger ones provide living accomodations for the men. As the squads must proceed on foot from the boats, these must serve as supply bases and consequently must store sufficient equipment for the operations.

The trolleys are small wooden platforms with steel wheels. They usually carry two men who alternately push the car along railroad tracks and who can easily move it off the tracks when they stop to spray. These men work only with DDT wettable powder for suspensions.

The men on horseback are employed in regions entirely inaccessible by other means of transportation. They take enough DDT wettable powder for at least one week's work and store it at a provisional base which is generally the house where they sleep. During the day they carry in canvas or leather bags enough DDT for a day's work.

The men who operate on foot, from trucks, motor-boats, or trolleys, or who ride horseback carry bags in which are small sacks of powder, each sack containing the proper amount to prepare a pumpful of suspension. They also carry a pail and an attached funnel for mixing the powder with water before filling the pump.

In small towns which require more than five days to be sprayed men work on foot using especially adapted wheelbarrows. These men work in pairs, with one wheelbarrow to each pair. The wheelbarrow tank holds about 200 liters of suspension which is prepared as needed. This not only eliminates motor transportation within the town but also the preparation of mixture each time the spray-pump is empty, saving money and time.

The Division Operations Manual (Manual de Procedimientos), Section K, Volume IV, is devoted to the DDT work and describes in detail the work of the squads and

of the DDT-insepctor. This manual has been indispensable for men who must perform duties which in other places would be done by persons with high school or college educations. Through the students to the International Malaria Courses, given each year from August to December in the Division, these manuals have become popular in other American republics where they have been adopted or modified according to local conditions.

MIXTURES AND EQUIPMENT

Specifications for the DDT mixtures used by the Division have been summarized elsewhere (Gabaldon 1949). Only technical grade DDT for solutions and 50 and 75 per cent wettable powders for suspensions have been used. These specifications were devised because most of the available products for suspensions are manufactured primarily for agricultural purposes where special equipment with mechanical agitators is used for spraying. When hand pumps are used, as in our program, the material may settle rapidly, and, unless the worker agitates the pump continuously, the amount of DDT per square meter is greater at the beginning than at the end of the operation. Furthermore quick wetting saves time in preparing suspensions. At the present time, four manufacturers in the U. S. A. are known to produce wettable powders according to our specifications. These specifications have been considered by the Committee on Specifications of the Pan American Sanitary Bureau and have been submitted in detail to the Expert Committee on Insecticides of the World Health Organization. Recommendations have been added concerning the prevention of caking in leftover suspensions and their resuspensibility. A problem still to be solved is the stability of the wettable powders which, particularly in reference to suspensibility, changes after one year of storage.

Since oil stoves are used widely for cooking, kerosene may be obtained readily in every small town at reasonable prices. Therefore, solutions are made *in situ* in the smaller tanks carried on the trucks. They are prepared in a 5 per cent concentration for use only on painted houses. Suspensions are employed on unpainted or white-washed houses. It has been shown (Maier, Rendtorff, and Suárez, 1948) that under our conditions DDT suspensions are active on mud walls for a much longer time than are solutions and emulsions. Since most of the rural houses in the malaria zone of Venezuela are made of this material more wettable DDT has been required than any other type. Emulsions have been used in small quantities because a cheap emulsifier cannot be obtained locally. The relative amounts of each mixture used in our work have been as follows:

MIXTURE	1946	1947	1948	1949
Suspensions	90.2	88.4	92.6	86.9
Solutions	9.8	10.3	7.0	13.0
Emulsions	0.0	1.3	0.4	0.1

The chemical laboratory plays an indispensable role in our organization. Before an order is given, 100-gm. samples of DDT collected from every tenth drum at the factory are sent by air from the U. S. A. to be tested. The sampling is done by an

officer sent from the Pan American Sanitary Bureau. This year the Savannah Laboratory of the Communicable Disease Center has been doing the testing for the Pan American Sanitary Bureau.

Several kinds of hand pumps have been employed for spraying, but we have found the one designed by Trapido (1948) best for our purposes. It is much sturdier and eliminates clogging by some suspensions. However, if suspensions made according to our specifications are used, clogging is of only secondary concern.

TABLE 2

Grams of DDT per square meter in each band of 5 cms. width of the upper, central, and lower portions of the spraying swath

5 CM. WIDE BANDS OF SWATH FROM LEFT TO RIGHT	UPPER PORTION	CENTRAL PORTION	LOWER PORTION
1	0.98	0.61	0.088
2	1.38	0.60	0.50
3	1.80	1.33	1.08
4	2.20	2.44	2.10
5	2.90	3.23	2.48
6	3.31	3.27	3.25
7	3.72	4.93	4.37
8	3.67	5.88	5.38
9	3.58	5.42	5.82
10	3.22	6.28	6.02
11	3.32	5.75	5.68
12	3.33	5.90	4.74
13	3.58	4.29	4.71
14	2.85	3.85	3.42
15	2.30	2.96	2.65
16	1.88	1.81	2.48
17	1.47	0.91	0.93
18	0.98	0.34	0.25
19	0.57	0.23	0.03
20	0.31	0.58	0.06

Nozzles constitute another problem. We prefer those which under 60 pounds pressure will deliver either 900 cc. or 1800 cc. per minute in a fan-shaped spray. The smaller one must be used for the type of pump described by Trapido (1948) to prevent clogging with suspensions. The second one, which will not clog, may be used with any pump. To insure an equal deposit of 2 grams per square meter (200 mgs./sq. ft.), concentrations of 5 per cent DDT must be used with the first nozzle and 2.5 per cent with the second which delivers double the amount of liquid per minute. These are applied at a velocity of 20–25 sq. meters (230 sq. ft.) per minute. It is not advisable to use the second nozzle for solutions since twice the necessary amount of kerosene or DDT would be applied. After from 20 to 30 days use with suspensions the spray hole enlarges allowing more liquid to leave per minute in a narrower spray pattern and consequently increasing the amount of DDT per square

meter. Another advantage of these two preferred nozzles is that spare tips or discs are available, and when change is necessary at approximately monthly intervals, only these parts need be replaced rather than the whole nozzle.

Experiments conducted in the Laboratories of the Division have shown that the fan-shaped spray produced by these nozzles is ellipsoidal in section. Thus, there is not a uniform amount of DDT deposit throughout the spray band, a higher concentration of the insecticide being present in the central part. Furthermore, as the distance from the nozzle to the wall varies according to the height from the floor, so does the amount of DDT deposit vary with the height, the upper parts of a wall receiving less (see Table 2). The quantity of liquid delivered by a nozzle is directly proportional to the pressure, the higher the pressure the larger the amount of liquid delivered. Approximately 3 per cent of the liquid from a nozzle which at 60 pounds pressure delivers about 900 cc. per minute falls to the ground, while only approximately 1 per cent falls from those nozzles which deliver about 1800 cc. per minute. In general, the narrower the nozzle hole the more liquid falls to the ground. From these statements it may be concluded that many variables influence the amounts of DDT deposited over sprayed surfaces. In addition to the personal factor, which probably is the most important of all, the amount of insecticide varies according to: the type and age of the nozzle, the concentration of the mixture, the speed of the spraying, the portion of the spray band, the height of spraying from the floor, and the pressure in the pump. Therefore, it is difficult to judge the efficiency of the spraymen by chemical analysis of wall scrapings unless a rather large number of samples is collected to obtain an adequate average. The same may be said for wall scrapings examined to evaluate the residual properties of DDT.

SPRAYING

Each squad leader receives a "plan of spraying" which outlines the names of the localities to be sprayed, the number of houses, the roads, the distance from the base, and the approximate time required for spraying. Each locality is selected according to the information available regarding its malaria problem or that of its environs. The number of houses and their distances from the base are ascertained during visits of rural visitors or the DDT-inspector. To facilitate local contacts the squad leader carries letters for such Public Health or Civil Authorities as may be present. Each "plan of spraying" lists a sufficient number of localities to cover one entire spraying cycle.

One member of the squad starts ahead of the group and marks the houses with the letters DDT and a number. At the same time, he informs the inhabitants that the house is going to be sprayed and tells them what to do regarding the disposition of the furniture and food. He also notes the number of inhabitants in each house.

All the houses of a selected locality must be sprayed. In towns of over 5,000 inhabitants, however, a central zone, where ordinarily no malaria vectors are found, is carefully selected by the chief of the service and delineated on a map. Once a locality is sprayed it continues to be protected during each spraying cycle. In the

future, when malaria disappears from any given area within the malaria zone, spraying for antimalaria purposes alone will be stopped. So far this phase has not been reached.

In general, the people want their houses sprayed. Houses closed because their inhabitants are working in the fields present the main difficulty. Some people have refused spraying because of sick persons or because it was siesta time and they did not want to be disturbed. The refusals have increased with time in some areas because people feel spraying is no longer necessary since fevers and mosquitoes have disappeared or decreased in number.

The whole interior of the house is sprayed: walls, ceilings, under parts of furniture. Verandas and the undersides of eaves are also protected. Not only are inhabited houses treated, but also uninhabited ones and other buildings such as stables, latrines, washing-places, etc. Spraying is done according to a set pattern to insure complete coverage.

The squad leader assigns to each man the houses he is to spray, checks the work in every house, and keeps an account of the number of houses sprayed and the liters of mixture and kilograms of DDT used in each locality. In this way we know the number of liters sprayed per man-hour, the number of houses protected per man-day, and the number of liters used per house, which are the principal data kept for comparison, and from which are obtained the costs per house and per inhabitant.

The squad is divided into groups according to the various methods of transportation. One man in each group is responsible for the work. He keeps the records, marks the houses, counts the inhabitants, asks them to prepare the house, and also sprays houses. The squad leader divides his time among the two or three groups into which the squad is divided.

SUPERVISION

The chief of the DDT field service, physician or engineer, is directly responsible for the work of the squad and supervises the carrying out of the spray plans. His assistant is the DDT-inspector who devotes his time to promoting squad performance. He makes two different types of visits, regular ones, in which he spends time with each man in order to observe the quality of his work and improve it where necessary; and unscheduled ones, to determine how closely the squad is carrying out the spraying plan and the work schedules. He also takes wall scrapings in order to check by chemical analysis the amounts of DDT deposited.

The DDT-inspector helps in the preparation of freehand maps, and adds to the available maps all new places which must be sprayed. In addition he must provide the necessary supplies to the squad, which is often not an easy task because of transportation difficulties. He makes a monthly report on the accomplishments of each squad in his zone.

As a help to the field services, the Central Office sends supervising inspectors to check the progress of the squad. With the DDT-inspectors they make a thorough study of the squad's organization and quality of work. From the reports available in the Central Office the supervising-inspector already knows the status of the squads

and which of them requires more attention. He also ascertains that all the regulations in the manual are followed exactly in the field.

During the first three weeks of each month, the DDT-Service of the Central Office receives a report of the work completed by each squad in the preceding month. Comparative graphs based on these reports are made and studied to ascertain any omissions in the work of some squads. Letters concerning these observations are then sent to the chief of the field service. In a kardex file a card is maintained for each sprayed locality recording the number of inhabitants, the number of houses protected during each visit of the squad, the number of the squad and the date of its visit, and the entomologic and hematologic findings supplied by the Section of Medical Activities and Epidemiology in the Central Office. Colored tabs indicate the occurrence of larvae of *A. albimanus*, *A. darlingi*, and other anophelines, or of positive slides so that a quick review of the file indicates where the vectors or infections are occurring. Thus inquiries may be conducted to classify possible failures.

PROGRESS OF THE WORK

In fiscal year 1945–46, when the DDT campaign was started, there was no special provision for this activity in the budget for the Malaria Division. The money spent was taken from the general budget of the Section of Anti-malaria Engineering. Since that time, however, amounts for the DDT work have been included as follows:

FISCAL YEAR	DIVISION BUDGET	DDT CAMPAIGN	PERCENTAGE
1946–1947	Bs. 8,143,420	Bs. 1,850,000	22.7
1947–1948	Bs. 10,537,600	Bs. 4,000,000	38.0
1948–1949	Bs. 12,653,424	Bs. 5,600,000	44.2
1949–1950	Bs. 13,121,388	Bs. 6,929,500	52.7
1950–1951	Bs. 13,917,132	Bs. 7,342,300	52.7

Contributions from the different states—more than Bs. 1,000,000—are included in the totals for fiscal periods 1949–1950 and 1950–1951.

These figures indicate the increasing role DDT has played in our work. Also it is worth noting that the total budget for the Division, which has enlarged continuously represents a per capita expenditure for the control of malaria and other metaxenous diseases of Bs. 3.10 (U. S. $0.89) in 1950–51, which is probably one of the larger amounts devoted to these activities by tropical public health administrations. This is a clear sign of the importance Venezuela has attached to malaria, which was one of the outstanding scourges of the country, and of the sound basis on which public health work is conducted in this Republic.

At present (June, 1950) there are 80 DDT squads in Venezuela, 46 of them using motor transportation, 10 travelling on foot (5 of which use wheelbarrows), 6 by motor boat, 17 on horse-back, and 1 by trolley. The trend today is to enlarge the number of the non-motor-transported squads in order to reach the more inaccessible places.

Due to the high cost of living in Venezuela, the salaries of the personnel engaged in DDT activities are high. These salaries include allowances for food and shelter during travel. In accordance with Venezuelan laws the workers are paid seven days

a week, although they work only six, and receive 15 days of paid vacation each year. Furthermore, if they are dismissed, they receive as severance pay one week's salary for 1 to 6 months of labor, and two weeks' for each year in the Service. Medical assistance is also given to them and their families. These conditions make it more convenient to keep trained men working all year round.

This system of a year-round program is not practical in other countries because DDT is only applied at or before the transmission season. But in Venezuela, as it should be in countries within the para-equatorial and equatorial climatic zones of malaria, transmission is decreased only during the dry season, and therefore year-round spraying is important. The presence of vectors inside houses during the dry season is an indication that transmission can be occurring. Confirmation that transmission is uninterrupted is shown by the fact that when DDT was sprayed in some towns (Gabaldon, 1949) at the beginning of the dry season, the malaria rates dropped to below the usual level for that season.

During 1946 the spraying cycle was of three months duration; it was increased in 1947 to four months; and in 1949 to six months. In 1946 and 1947 the rate of spraying was one gram per square meter (100 mgms. per sq. ft.). This was increased to two grams by the end of 1948. The short cycles at the beginning of the work were established on the basis of data published up to that time regarding the residual power of DDT. It was necessary for us to attack malaria as vigorously as possible and we could not take any chances. However, results indicated that the cycles could be increased to six months; but we do not think they can be expanded further because either the cleaning of walls or the accumulation of dust on them may nullify the effect of the insecticide. However, for greater efficiency, these cycles may have to be reduced, as will be shown below. It should be added that the increase from one to two grams per square meter was done because the six-month cycles were adopted and not because one gram failed to control malaria.

In Table 3, data pertaining to the development of the DDT malaria campaign in Venezuela are presented. In 1949, 70.3 per cent of the 507,773 houses which needed spraying were sprayed. This is a high proportion if one recalls the difficulties presented by the sparsely populated rural areas. As may be seen in the table this percentage has been rising each year. The number of sprayed localities has increased more than 20 times since 1946, from 272 to 5,771. The small number of houses (62) per locality is an indication of the scattered population. The number of houses sprayed has increased similarly. In 1949, 356,981 houses were actually sprayed although the area covered involved more than 400,000 houses. The remainder was not sprayed for a number of reasons such as absence of the inhabitants, houses under construction at the time of the visit, or refusal by the inhabitants. In 1949, 1,697,903 inhabitants were protected directly by DDT, but some 2,000,000 or more must have been indirectly protected because many inhabitants of the central parts of larger towns are protected by the ring-like zone of sprayed houses around these towns. The rise in the percentage of the total program cost used for DDT is due to more skillful and thus more complete application and to the increase from one to two grams per square meter. This amount is proportionately lower than those for other countries (Pampana 1948). This is probably the result of the high cost of labor in

Venezuela and of the difficulties involved in reaching houses to be sprayed. The cost per inhabitant per spraying is also high compared to the values presented by Pampana (1948). To ascertain the cost per inhabitant per year multiply the figures in Table 3 by 2 or 3 according to the number of sprayings. With the exception of 1948, these sprayings, which should be two per year, have been less because the number of sprayed localities is increasing constantly and some houses are sprayed twice and others only once.

During the early years, as the program expanded from the zones with better means of communication and more concentrated populations to include the more isolated areas, the problems and the costs necessarily increased. However, our efforts to improve the workers' skill have brought about a reduction in cost for 1949. The growing efficiency in operation is shown in Table 4 where a comparison with data from the United States of America is presented. In the more accessible zones, where

TABLE 3

Progress of the DDT spraying program in Venezuela

	1946	1947	1948	1949
Localities sprayed	272	1,251	2,498	5,771
Average number of houses in each	64	66	67	62
Sprayings per year	1.7	1.9	2.2	1.6
Number of houses protected	17,311	82,388	168,472	356,981
Number of house sprayings	28,905	156,997	372,160	585,434
Number of persons protected	89,055	414,538	863,498	1,697,903
DDT used (kgms.)	7,791	51,779	165,999	277,601
Grammes DDT per spraying per capita	55	66	88	99
Cost of DDT as percentage of total	18.0	22.9	28.6	27.3
Cost per inhabitant (bolivars)	2.12	2.18	2.18	1.70
Houses to be sprayed	433,878	443,238	452,615	507,773
Percentage of houses sprayed	4.0	18.6	37.2	70.3

the work has been going on for two or three years, the cost has been diminishing since the beginning. But, as there are regions of both types in each State, this decrease was not observable for the whole country until 1949. In order to foster improvement in the quality and quantity of work, prizes are awarded every three months to the five best squads. Each man of the favored squad receives a sum equal to one week's pay. With this objective in mind, the quick workers in each squad supervise the slower ones and stimulate them to attain the goal set by the squad leader. In grading each squad, proper consideration was given to local labor conditions.

Table 3 shows that the number of houses to be sprayed is increasing every year, as the population increases. This number, based on the 1936 and 1941 Censuses of Venezuela, does not mean that the malaria zone is enlarging to include new territory. This probably is an overestimated number, but in planning a malaria eradica-

tion campaign it seems better to overestimate than to underestimate. Many areas which have not yet been sprayed are borderline regions where malaria either has a low prevalence or disappears periodically. The zone where malaria incidence is greatest has already been sprayed with the exception of small pockets which have necessarily been omitted. Therefore, the great reduction in malaria is the result of the investigations conducted prior to the program's inception and of the resultant concentration of activities in localities where the malaria burden was heaviest. Our present objective is to spray all the remaining pockets in a last but difficult and expensive effort to see if large areas can become entirely free of malaria. If malaria is maintained in the borderline regions named above only by introduction from the heavily infected areas, it is very probable that the reduction of malaria in these latter areas will prevent extension to the former, and, therefore, the number of

TABLE 4

Comparison of work with DDT

YEAR	GMS. DDT PER HOUSE	HOURS PER HOUSE	GMS. DDT PER HOUR
United States of America*			
1947	388	1.32	294
1948	512	1.36	377
1949	597	1.50	398
Venezuela†			
1947	330	2.38	139
1948	446	2.02	220
1949	474	1.53	310

* After P. A. Stephens, (1950).

† Data from Division de Malariologia.

houses still to be sprayed will be lower than stated in Table 3. For instance, the very favorable results obtained from the States of Aragua, Carabobo, and Yaracuy, referred to below, followed the spraying of only 78.2 per cent of the houses which, according to the estimate, needed to be sprayed.

CONTROL OF EFFECTS

In the sprayed areas, which now cover practically the entire malaria zone of Venezuela, two considerations are kept carefully in mind: (a) the presence of malaria cases and of vectors inside houses, and (b) the houses which have not been sprayed.

The detection of one person with malaria parasites in his blood should be considered as a failure of DDT. The known failures of DDT are not of the insecticide itself, but of its application. So few relapses were observed after the first two years of spraying that our practice has been to call every patient with malaria a "new" case, unless the contrary can be proved. The nurses in most of the medical dispensaries scattered throughout the country are paid five bolivares (= $1.50) for each positive slide they take from patients with fever. Payments have become so few in a number of places that some of the nurses have to be paid a fixed sum to preserve

their interest in this field. These cases, and those found by rural health visitors in their house to house search for fever patients, receive careful study in order to establish the origin of the infection.

Generally it is found that people with malaria parasites live in unsprayed houses. These houses fall into two groups: 1) those which were not sprayed by the spraying squad, and 2) those which have been recently repaired or painted, or those which are being built in certain zones of recent exploitation. The first group is generally a small one as people rather like to have DDT sprayed in their homes and the second group varies according to the region. In some instances, the discovery of one malaria case has uncovered an unmapped area which is then incorporated into the regular spraying cycle. It is interesting to note that on our western border the apprehension of a malarious person without a permit to travel abroad may lead to the identification of a smuggler.

In zones where many houses are being built, auxiliary squads cover the newly finished homes between the two spraying cycles. In other places, the health visitor's duties have been expanded to include the occasional spraying of a new house or of a recently repaired or painted one. Thus, most of the houses of the malaria zone are protected throughout the year. This is a basic concept for malaria eradication, not easily attained in an underpopulated country where seasonal conditions, such as floods during the rainy season, contribute to the difficulty of regular coverage for all houses. The future of malaria in Venezuela depends upon the solution of this problem. But the writer feels sure that this difficult task will be conquered by the energy and the ingenuity of the workers in the Malaria Division.

RESULTS

A detailed account of the results obtained up to 1948 in the nationwide DDT malaria campaign in Venezuela has been presented elsewhere (Gabaldon, 1949). The conclusions reached regarding this disease may be summarized as follows: (a) a general decrease in the spleen index which was more marked in zones with a high ratio of epidemicity and a low ratio of endemicity; (b) a similar effect in the average spleen; (c) a marked reduction in morbidity and mortality wherever DDT was sprayed; (d) a decrease in the relative proportion of *Plasmodium falciparum* and an increase in that of *Plasmodium vivax*; (e) in the same locality more cases of malaria from houses left unsprayed than from those sprayed, a new proof that malaria is a house infection; (f) a remarkable reduction of the adult density index of *Anopheles darlingi* in sprayed houses, with a similar diminution in the larval density index of this species and its apparent eradication from certain areas; (g) the same for *Anopheles albimanus* adults but not for the larvae; and (h) no changes in the larval density index of other common anopheline species from DDT spraying.

Beyond these specific effects on malaria, it was stated in the paper mentioned above that DDT spraying apparently had some influence in other fields related to health. These were: (a) a reduction in fly populations, particularly after the first sprayings, which contributed to the decrease in mortality from diarrhea and enteritis; (b) the eradication of *Aedes aegypti* from sprayed towns thereby eliminating all possible urban infection with jungle yellow fever; and (c) an increase of *Rhodnius*

prolixus in the sprayed houses of some areas, possibly as a result of the disappearance of natural enemies eliminated by the insecticide.

The effects on malaria prevalence during the four-year DDT program are presented in Table 5 where the three regions into which Venezuela was divided are considered separately. The data shown in this table have been collected from four different sources; (a) the percentages of DDT-protected houses are obtained from the field DDT spraying services and represent the proportion of houses in the malaria zone of each region which have received the insecticide regularly; (b) the malaria death rates are based on death certificates signed by government or private physicians working in these areas; (c) the treatments per 1,000 inhabitants represent the work done at more than 2,000 drug distribution posts scattered throughout the malaria

TABLE 5

Effect of DDT on malaria prevalence in the three regions in which Venezuela has been divided

DATA AND REGIONS	1941–1945	1946	1947	1948	1949
Percentage of DDT protected houses:					
Costa-Cordillera	0.0	5.2	15.6	36.5	72.8
Llanos	0.0	2.3	22.0	36.3	64.0
Guayana	0.0	4.0	35.0	53.3	76.6
Malaria death rates:					
Costa-Cordillera	93	45	28	13	7
Llanos	217	106	61	24	17
Guayana	121	62	56	14	7
Treatments per 1000 inhabitants:					
Costa-Cordillera	98	93	76	59	40
Llanos	317	286	230	178	131
Guayana	356	324	321	224	164
Parasite infection index:					
Costa-Cordillera	23.6	15.4	19.8	25.9	13.6
Llanos	32.0	22.1	12.1	9.3	8.0
Guayana	21.2	19.7	30.2	3.6	4.2
Positive slides per 100,000 house visits:					
Costa-Cordillera	1376	753	844	645	368
Llanos	2300	1194	422	257	195
Guayana	1520	814	358	162	100

zone, staffed by school teachers and post and telegraph officers who distribute envelopes containing tablets for an entire course of quinine and later of atabrine to anyone requesting antimalaria treatment for themselves or their families; and (d) the parasite infection index and the positive slides per 100,000 house visits are based on the work of health visitors who go from house to house in the malaria zone looking for people with fever and taking blood smears (thick and thin films) from them. Some of the apparent discrepancies in Table 5 can be explained by the fact that the material therein came from such varied sources.

In the 20 years before DDT was introduced, the Llanos ranked first in malaria prevalence, Guayana second, and Costa-Cordillera third, as shown in Table 1. The population per square kilometer in these regions is as follows (1941 census) Costa-

Cordillera 16.0, Llanos 2.2, and Guayana 0.2. The percentage of rural population also differs in these regions: Costa-Cordillera 62.7, Llanos 72.3, and Guayana 59.5. Even though the population density in Guayana is low, it is the large rural distribution in the Llanos which presents the most difficult problem. This again should be taken into consideration when interpreting the data in Table 5.

Up to 1948, the DDT program was directed towards the more accessible places. Since the end of that year, and particularly throughout 1949, an effort has been made to spray all houses in the malaria zone. The percentages of houses DDT-protected in 1949 fall into this descending order: Guayana, 76.6; Costa-Cordillera, 72.8; and the Llanos, 64.0. In 1948, spray coverage in Guayana was the most complete and, consequently, the drop in the malaria death rate was largest in this region. In 1949, the Costa-Cordillera and Guayana reported the highest numbers of protected houses and the lowest malaria death rates. These rates, therefore, have been affected directly by DDT spraying.

In spite of the low malaria prevalence in Guayana, the higher proportion of rural population in the Llanos has resulted in the number of treatments per 1,000 inhabitants being larger in the former. This probably explains why in 1949 the number of treatments in Guayana did not decline after DDT spraying as did the death rates.

The DDT squads are provided with transportation, but the rural health visitors are not. Therefore, it is more difficult for this last group of workers to reach the sprayed localities in the Llanos than in the other two regions, the Costa-Cordillera, with its high population density, being the easiest of all. Because of this (Table 5) the parasite indexes presented to not correspond closely with the data on deaths and treatments. In any case, these parasite indexes indicate the great reduction in malaria parasite prevalence which has followed DDT spraying. The figures for the Costa-Cordillera probably indicate actual conditions more closely than do those for the other two regions. On the other hand, they may represent an over-estimation since emphasis is placed on examining those areas where the probability of finding malaria cases is greater.

Let us see now the effects of DDT on the health of the country as a whole. In Table 6, malaria death rates, birth rates, general death rates, and vital indexes are presented. Malaria deaths have dropped to 8.04 per cent of the 1941–1945 median, which is a great reduction. The birth rate increased by 7.2 per 1,000 inhabitants, apparently as a result of the better health enjoyed today by people who used to suffer from malaria. The general death rate decreased by 3.8 per 1,000 inhabitants, nearly one-third being due to the reduction in malaria mortality, and probably another third to the indirect effect on general mortality attributable to reduced malaria prevalence. As a result of these changes in natality and mortality, the vital index has increased tremendously.

The vital statistics figures from tropical countries are generally regarded as misleading and little attention is paid to them. A critical review of the Venezuelan data for the period 1905–1945 was presented by Gabaldon and de Pérez (1946) with particular reference to malaria mortality. The conclusion reached was that even if the rates did not indicate actual conditions, they did show clearly the trends of the

studied phenomena. For the period 1937–1941, it was found that apparently due to under-registration three deaths per 1,000 inhabitants were lost. This figure has probably fallen to two per 1,000 in the last few years as a result of improvements in the services concerned. With this correction, the general death rate for the Republic in 1949 would have been 14.5 instead of 12.5.

In three States (Aragua, Carabobo, and Yaracuy), with about 500,000 inhabitants, death registration is very accurate and 62.5 per cent of deaths are certified by doctors (Gabaldon and de Pérez, 1946). Here the malaria death rate per 100,000 has declined from a median of 173 in 1941–1945 to two in 1949, and the general death

TABLE 6

Direct effect of DDT on malaria mortality and possible collateral effects on some health indexes in Venezuela

DATA	1941–1945	1496	1947	1948	1949
Malaria death rate	112	54	33	14	9
Birth rate	36.1	38.4	39.5	40.7	43.3
General death rate	16.3	15.0	13.9	13.3	12.5
Vital Index	222	256	284	310	346

TABLE 7

The index of positive slides per 100,000 house visits in relation to the number of months after spraying in some areas of the States of Aragua, Carabobo and Yaracuy which received 12 sprayings during the period 1946 to 1949

MONTHS AFTER SPRAYING	1ST TO 4TH SPRAYING			5TH TO 8TH SPRAYING			9TH TO 12TH SPRAYING		
	Visits	Cases	Index	Visits	Cases	Index	Visits	Cases	Index
1–2	43,280	105	243	27,852	15	54	12,631	4	32
3–4	17,672	17	96	12,509	5	40	7,056	1	14
5–6	5,338	5	94	4,462	2	45	3,578	1	28
Total	66,290	127	192	44,823	22	50	23,265	6	26

rate from 22.0 per 1,000 to 13.9. These more precise figures support what was observed regarding mortality for the country as a whole. In these States, the number of positive slides per 100,000 house visits indicates a very clear reduction of the disease. This index falls from a median of 1,083 in the period 1941–1945 to 338 in 1946, 136 in 1947, 82 in 1948, and 32 in 1949. In some areas of these States which have been sprayed 12 times since 1946, the indices of positive slides per 100,000 house visits fell from 192 during the first four sprayings to 26 during the last four (Table 7); but it may be noted that during the fifth and sixth months after spraying this index has a tendency to increase. Therefore, some transmission must have occurred during these months. These and similar results obtained from other zones may indicate that the interval of six months between sprayings is too long. Careful consideration is being given to this situation at the present time since it may require a return to the old four-months spraying cycle. Nevertheless, if malaria continues to subside as it has up to the present, it may be cheaper to continue the longer

spraying cycle, although it may take longer to achieve eradication. But since, on the basis of the paraquinquennial non-annual cycle of malaria, an increase in malaria morbidity is expected during 1950 to 1952, we may find that the six-month spraying cycle will be unable to cope with a situation of exceptionally high transmission. This fact should be remembered by those who over enthusiastically advise longer spraying cycles.

In considering the general results presented above, it should be remembered that they relate to a population of more than 4,000,000 scattered throughout an area of nearly 1,000,000 square kilometers. The health conditions they represent are similar to the prevailing ones in Southern Europe whence rather large masses of people are moving to Venezuela. As malaria has interfered with the development of large zones in this country, its disappearance should be followed by the settlement of these areas by immigrants and by people inhabiting poorer lands in other sectors. Therefore, new opportunities, unsuspected in the past, are open today to our fellow countrymen.

DISCUSSION

The theoretical backgrounds on which our campaign against malaria in Venezuela has been based were discussed at length elsewhere (Gabaldon, 1949). The results presented above clearly indicate that complete disappearance of malaria from the country should be expected in the near future. We contemplate, therefore, radical changes in the health, social, and economical conditions of this Republic, probably the only true revolution she has suffered in the last decades. The most important effects of these changes may be summarized as follows:

(1) A decrease in the number of deaths and an increase in the number of births, which have caused a growth of the population at a speed previously unknown;

(2) As a result, a sudden expansion of the economically dependent population, both infant and aged, and, therefore, a proportional reduction of the economically active adult population, a factor that has aggravated the country's production needs;

(3) An increase in the number of inhabitants in the more malarious rural zones, where the racial constitution is poor and the educational level low, which has produced a rupture in the social structure of the country; and

(4) An abrupt appearance of large areas of fertile land, heretofore untenable, which, if not properly tilled immediately, may constitute an economic loss due to poor production and/or soil degradation.

In this way, the malariologist has altered radically the ecology of man. Therefore, the aim of public health activities should be not only to promote health and to reduce morbidity and mortality, but to enhance the general environment so that the fundamental desire of a nation for the full development of its resources may be realized. Consequently, the malariologist, along with other public health officers, cannot be only a statesman of the health, but has to become a statesman of the population. In this wider field he surely will not find an end to his activities.

SUMMARY

The story of a nation-wide malaria control program with DDT in Venezuela is presented. This work has been carried on since the end of 1945 with ever increasing

intensity until today 70 per cent of the houses in the malaria zone are protected regularly twice a year. The remaining 30 per cent consists of isolated groups of as yet unsprayed houses in rural areas. At the present time, all efforts are being directed toward incorporating these into the routine program.

The methods employed and the equipment used are described thoroughly. They are specially fitted for work in an underpopulated tropical country where labor conditions are costly. They are also adapted to be carried out in the field under the direction of workers who do not have adequate educations.

An extraordinary reduction in malaria prevalence has occurred as shown by the usual malariometric indices. The malaria death rate for Venezuela has fallen from a median of 112 in 1941–1945 to nine in 1949. As a result of this change in malaria prevalence and mostly due to it, the general death rate decreased in the same period from 16.3 to 12.5 and the birth rate increased from 36.1 to 43.3. These facts represent the greatest change Venezuela has ever had in her health conditions.

REFERENCES

Gabaldon, A. 1949. The nation-wide campaign against malaria in Venezuela. Trans. Roy Soc. Trop. Med. & Hyg. **43**: 113–160.

Gabaldon, A. and de Pérez, G. G. 1946. Mortalidad por malaria en Venezuela. I. Bases estadísticas y distribución geográfica. Tijeretazos sobre Malaria **10**: 191–237.

Maier, J., Rendtorff, R. and Suárez, M. A. 1948. The duration of residual effect of DDT on building materials used in rural Venezuela. Am. J. Trop. Med. **28**: 889–894.

Pampana, E. J. 1948. La lutte antipaludique par l'aspersion des locaux a dichlor-diphenyl-trichloretane (DDT) a effet remanent. Bull. Org. Mond. Santé **1**: 281–330.

Stephens, P. A. 1950. Accomplishments and costs of the residual spray program, F. Y. 1947–1949. Communicable Disease Center Bulletin **9**: 20–21.

Trapido, Harold. 1948. The development of a sprayer for use with water suspensions of DDT in rural areas of Latin America. Am. J. Trop. Med. **28**: 721–739.

RESUMEN

Se ha presentado la historia de un programa nacional de control de malaria con DDT en Venezuela. Este trabajo se ha llevado a cabo desde últimos de 1945 con una creciente intensidad hasta que hoy 70 porciento de las casas en la zona malárica se protegen regularmente dos veces al año. El 30 porciento restante consiste de grupos aislados de casas aún no rociadas en áreas rurales. En el presente, todos los esfuerzos van dirigidos a incorporar éstas en el programa rutinario.

Los métodos y el equipo usados se han descrito minuciosamente. Éstos son especialmente adecuados para trabajo en un campo tropical de población baja donde las condiciones de labor son costosas. Ellos también son adaptables a ser llevados al campo bajo la dirección de trabajadores que carecen de educación adecuada.

Ha ocurrido una extraordinaria reducción en la preponderancia de malaria como lo demuestran los índices malariométricos. La proporción de muertes de malaria en Venezuela ha decrecido de un promedio de 112 en 1941–1945 a 9 en 1949. Como resultado de este cambio en la preponderancia de malaria y mayormente debido al mismo, la proporción de muertes general se redujo en el mismo período de 16.3 a 12.5 y la proporción de nacimientos aumentó de 36.1 a 43.3. Estos hechos representan el cambio más grande que ha tenido Venezuela en sus condiciones sanitarias.

NATION-WIDE MALARIA ERADICATION PROJECTS IN THE AMERICAS

Dr. Russell: The next speaker was born in Italy and educated in Italy and England, graduating with honors from the University of Pisa, earning a Diploma in Tropical Medicine and Hygiene in London, and a Diploma from the Superior School of Malariology in Rome. He is a member of the Royal College of Physicians, London, and an Honorary Lecturer in Tropical Pathology at the University of Pisa. At the present time he is Medical Adviser, British Guiana Sugar Producers' Association, and Honorary Government Malariologist. He is a member of the WHO Panel of Malaria Experts and the author of numerous papers on malaria epidemiology and control. Working with small budgets and against many environmental difficulties but with that vital singleness of purpose he has carried forward one of the outstanding malaria eradication projects of the Americas. It is a pleasure to introduce as our next speaker Doctor George Giglioli.

III. ERADICATION OF *ANOPHELES DARLINGI* FROM THE INHABITED AERAS OF BRITISH GUIANA BY DDT RESIDUAL SPRAYING

GEORGE GIGLIOLI*

British Guiana lies on the northeast coast of South America wedged between Venezuela, Brazil, and Dutch Guiana (figure 1). It covers an area of approximately 83,000 square miles and offers a fair cross-section of the whole Guiana region in its physiography, climate, fauna, and flora. The climate is typically equatorial with heavy, well distributed rainfall (average mean temperature 81°F.; average relative humidity 82 per cent; average annual rainfall 95 inches).

The present day population of the colony can be estimated at 425,000, nearly nine-tenths of which is settled in the coastal plantation belt. This is a narrow fringe, only five to ten miles deep, extending for some 280 miles along the Atlantic seaboard and along the banks of the Essequibo, Demerara, Berbice and Corentyne River estuaries. In the interior, approximately 50,000 inhabitants are widely scattered in small settlements along the lower tidal reaches of the rivers, in mining and timber camps, in the Amerindian settlements of the Pakaraima plateau, and in the Rupununi-Takatu savannahs.

Until recently malaria was endemic, hyperendemic or epidemic throughout the whole of British Guiana; in the densely populated coastal belt, lying mostly below high tide level, artificial factors greatly aggravated the problem. Sea dykes, precluding tidal flooding by sea water and an enormous network of irrigation canals and drainage trenches, coupled with the peculiar forms of wet cultivation inherent in the production of sugar cane and rice, the staple crops of the country, have made ideal conditions for the production of *Anopheles darlingi*, *A. aquasalis*, *A. albitarsis*, and *A. triannulatus* at all seasons of the year in and around inhabited areas. Even in Georgetown, with over 90,000 inhabitants, closely surrounded on two sides by irrigated rice and sugar cane, the suburbs were formerly subject to severe endemic malaria.

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On the coast, between the estuaries of the Berbice and Corentyne Rivers, agriculture is less advanced and sea defences and irrigation are deficient, so that extensive brackish marshes surround most of the villages. Here *A. aquasalis* and *A. albitarsis* abound, but under average conditions *A. darlingi* was not found, and the incidence of malaria was very nearly negligible. Only in years of exceptionally high and prolonged summer rainfall *A. darlingi* might temporarily invade the area from its endemic haunts on the Berbice estuary, causing sharp epidemics of the disease.

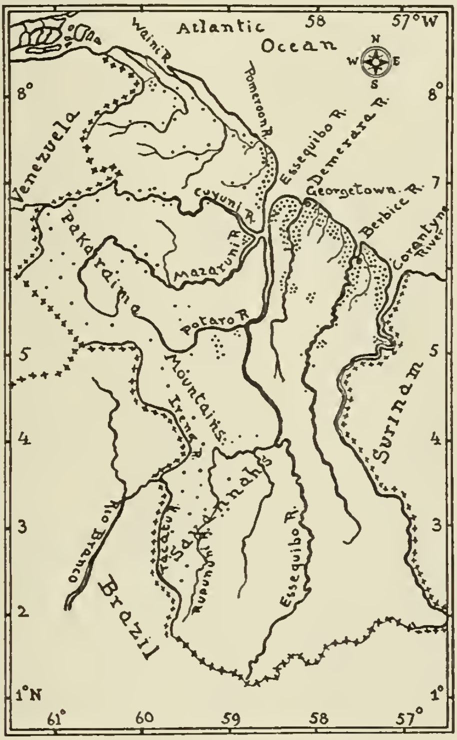

FIG. 1. British Guiana has an area of 83,000 square miles, 90 per cent covered by equatorial rainforest. The population of 425,000 is settled mainly on the narrow coastal plantation belt. In the interior some 50,000 inhabitants are widely scattered along the lower reaches of the larger rivers, on the Rupununi savannahs and on the Pakaraima plateau. The dotted areas indicate the distribution and density of the population.

Identical conditions existed on the western coastlands of Berbice, east of the Abary River.

The peculiar configuration, complex hydrological conditions, and favourable climate prevailing throughout the coastlands of British Guiana had rendered malaria control by classical drainage and anti-larval techniques completely impossible, physically and economically. It was evident, moreover, that further agricultural development of the coastlands requiring more sea defences, and irrigation and drainage canals necessary for wet cultivation of rice and sugar cane, necessarily implied an extension of the basal conditions underlying our malaria problem.

In the Colony's interior, extensive uncontrollable seasonal flooding of vast tracts of low-lying forest and savannah lands produced similar hydrological problems. As a result of these conditions prevailing throughout this region, the cost of adequate preventive measures by drainage or anti-larval methods would, in most cases, have been out of proportion to the population involved. Mineral and timber exploitation, and even travel in the interior, has been seriously handicapped by malaria in the past. Here again interference with the local distribution of surface waters has had a pernicious aggravating influence on malaria incidence, notably in hydraulic mining,

TABLE 1

Relative incidence per cent of various anopheline species in houses and in surface waters before DDT control

YEAR	TOTAL COLLECTED	*A. darlingi*	*A. aquasalis*	*A. albitarsis*	*A. triannulatus*
Morning adult captures in houses					
1939	24,683	98.1	1.3	0.5	0.0
1940	8,452	48.5	50.1	0.4	0.0*
1941	2,800	58.4	39.8	1.4	0.3*
1942	11,687	90.8	7.6	1.0	0.5*
1943	12,768	96.2	2.5	0.7	0.6
1944	14,659	96.2	2.6	0.9	0.1
1945	14,357	99.9	0.05	0.01	0.0
Total..................	89,406	91.0	8.1	0.6	0.2
Larval captures in adjacent breeding-areas					
1939	10,005	17.6	37.5	20.8	23.9
1940	16,145	8.8	70.4	11.3	9.4*
1941	8,663	0.5	84.1	2.7	12.7*
1942	6,849	6.1	73.4	9.8	10.6*
1943	21,434	26.7	27.7	26.6	18.8
1944	7,524	17.5	49.8	16.0	16.5
Total..................	70,609	17.5	49.8	16.0	16.5

* (During the 1939–40 drought, salt water was let into irrigation canals.)

ore-washing for bauxite or gold, gold and diamond placer mining and prospecting, gold dredging, and logging operations.

Anopheles darlingi is practically the sole transmitter of malaria in British Guiana; it is an anthropophilic mosquito with distinctively domestic feeding and resting habits; moreover, it is the most dangerous and widely distributed malaria carrier of tropical South America, east of the Andes. *Anopheles aquasalis*, *A. albitarsis*, and *A. triannulatus* are common and widely distributed species, but they are largely zoophilic and non-domestic (table 1). In the presence of a large reservoir of gametocyte carriers, under *A. darlingi* transmission, it is probable that these three species formerly acted as occasional or accessory carriers. In the sparsely inhabited lower

reaches of the numerous rivers of the North West District of the Colony, an area practically devoid of livestock and probably free from *A. darlingi*, *A. aquasalis* appears to be somewhat more anthropophilic, and is probably responsible for the low to moderate malaria endemicity found there.

Systematic research on malaria epidemiology and mosquito biology was begun on the sugar estates of the Colony in 1933; these studies were intensified between 1939 and 1944 under a cooperative scheme financed jointly by the Colonial Government, the British Guiana Sugar Producers' Association and The Rockefeller Foundation. Dr. George Bevier represented the Foundation in the Colony from 1940 to 1946, and took personal charge of malaria investigations from June 1940 to the end of 1942. A large amount of valuable data on the malaria problem and on the ecology of the indigenous anophelines was obtained, but no control measures applicable to our peculiar conditions were developed.

Such was the situation in British Guiana in January 1945, when the first DDT residual spray experiments were begun. Our previous knowledge of the feeding and resting habits of *A. darlingi*, together with the wealth of up-to-date epidemiological and ecological data available, enabled us, *ab initio*, to use the new insecticide intelligently and appropriately, under sound experimental conditions. We were fortunate at this stage to have the help and advice of Messrs. C. B. Symes and A. B. Hadaway, who visited the Colony from February to April 1945 on behalf of Great Britain's Colonial Office. The experimental spray program expanded rapidly; by the end of 1946, densely populated districts on the Demerara and Berbice River estuaries, with a rural population of approximately 60,000, were included in the experimental area. The results of the preliminary experiments were so satisfactory that on 1 January 1947 a colony-wide, systematic DDT residual spray compaign was begun under the joint cooperation of the Mosquito Control Service of the Medical Department and the sugar industry. The latter controls on its plantations about 75,000 people, nearly one-fifth of the population of the Colony. By December 1948, 90 per cent of the total population was protected; 95 per cent at the end of 1949; and at the time of writing (October 1950) it is estimated that 98 per cent of the population is protected, including most of the Amerindian settlements in the remote and almost impenetrable interior.

The salient features of our campaign can be summarised as follows: On the coast of British Guiana the great majority of houses are wooden structures, but mud-and-wattle huts are not rare in the rural districts; in the interior, wood, split palm trunks, palm leaves, tree bark, mud-and-wattle, and sun-dried bricks are used in construction. Wooden walls and ceilings, if oil-painted, are practically non-absorbent; on these a 5 per cent solution of DDT in kerosene gives an adequate residual deposit without causing damage. On rough unpainted boards and other absorbent materials, a 10 per cent suspension of wettable powder containing 50 per cent DDT is applied. Emulsions are used only in the interior where a transportation problem exists. The target residual dosage is 150 milligrams of DDT per square foot.

After experimenting with a variety of apparatus, including power, pressure, and knapsack sprayers, we have adopted the Cooper stirrup pump as standard equipment. Angulated nozzles giving a uniform conical spray, and leak-proof clamp cut-

offs are of local design and manufacture, and are described elsewhere (Giglioli, 1948). Pumps are usually equipped with two nozzles and are operated by a three-man team. All interior surfaces of the houses are treated to the height that can be reached with a three-foot spraying lance; the under and back surfaces of furniture and bedding are also sprayed.

The Public Health Ordinance has been modified to make DDT spraying compulsory in designated areas. In rural districts all houses are treated; in the cities spraying is limited to houses in the suburbs and peripheral areas, on the barrier principle.

The Government Mosquito Control Service, with 70 employees, controls an area with a population of roughly 340,000. On the sugar estates 14 men, with the part-time services of a medical officer, a senior supervisor, and a clerk, control malaria in an entirely rural population of 75,000. In the interior, spraying is carried out by a four-man squad, transported by launch. In the inaccessible Indian settlements of the western highlands and southern savannahs, dispensary rangers, travelling by boat, horse, or on foot, carry out spraying once a year with local voluntary help.

The interval between sprayings has been modified in the light of experimental work and experience: In 1946–47 it was eight months; in 1948–49 twelve months; in 1950 it was increased to eighteen months.

It is important to note that no control measures against anopheline larvae were conducted from 1945 to the time of writing.

Expenditures expressed in B.W.I. currency ($1 U.S. = $1.70 B.W.I.) can be summarised as follows:

YEAR	1947	1948	1949	1950
Mosquito Control Service	$117,580	143,285	126,757	114,520
Sugar Estates	34,737	38,485	35,514	34,784
Total	$152,317	181,770	162,271	149,304
Cost per capita	0.389	0.451	0.391	0.35

For checking the results of the campaign we have used the following methods and returns:

(1) Entomological surveys based on mosquito captures in houses and larval collections from surrounding potential breeding-areas throughout the controlled area (tables 2 and 3).
(2) Malariometric surveys of school children (table 4).
(3) Parasite surveys of infants born in 1949 and 1950 on sugar estates previously subject to hyperendemic malaria.
(4) Examination of slides sent by medical practitioners from suspected cases of malaria.
(5) Morbidity returns from sugar estates hospitals (clinical diagnoses only) (figure 2).
(6) Morbidity and mortality returns provided by weekly malaria notifications from medical practitioners (clinical diagnoses only in great majority of cases) (figure 3).

(7) Colony and sugar estates vital statistics (tables 5 and 6, and figures 4 and 5).

After all the houses of a locality have been sprayed with DDT, house captures of *A. darlingi* become negative immediately; within two to four weeks the larvae of this species also disappear from their usual breeding-places in spite of the continued

TABLE 2

Anopheline captures in houses (hand and "flit" captures) before and after DDT control

YEAR	ROOMS EXAMINED	*A. darlingi*	*A. aquasalis*	*A. albitarsis*	*A. triannulatus*
Before DDT Control					
1944	22,415	14,107	395	143	18
After DDT Control					
1947	2,251	5	7	0	0
1948	1,559	0	26	0	0
1949	517	0	65	24	1
1950	6,820	0	12	8	0

TABLE 3

Relative incidence of A. darlingi larvae in surface waters before and after DDT residual spraying of houses

YEAR	WATERS EXAMINED	NO. POSITIVE FOR *A. darlingi*	PER CENT POSITIVE	NO. OF LARVAE COLLECTED
Before DDT Control				
1939	1,594	326	20.4	1,397
1940	3,305	226	6.8	1,310
1941	903	2	0.2	2*
1942	6,700	94	1.4	482*
1943	11,199	1,299	11.6	5,751
1944	11,402	1,208	10.6	5,432
After DDT Control				
1946	3,823	3	0.09	3
1947	8,954	0	0.0	0
1948	4,587	0	0.0	0
1949	1,886	0	0.0	0
1950	8,059	0	0.0	0

* Effect of 1939–40 drought; salt water let into irrigation canals in March 1940.

presence, in unchanged numbers, of larvae of other anophelines. Residual DDT, therefore, not only specifically eliminates adult *A. darlingi* from the houses but also causes oviposition to cease entirely; this indicates that all mosquitoes of this species enter houses and make lethal contact with the insecticide. It can therefore be stated categorically that DDT has no repellent action on *A. darlingi*.

TABLE 4

Malariometric indices in school children on the British Guiana coastland before and after DDT control 1943–1950

DISTRICT	POPULATION (1949)	CHILDREN EXAMINED	SPLEEN RATE	AVERAGE ENLGD. SPLEEN	AVERAGE SPLEEN	PARASITE RATE	GAMETOCYTE CARRIER RATE	ENDEMIC INDEX	PARASITE COUNT
Before DDT (1943–45)									
Rural Areas									
Essequibo Coast	22,734	525	57	2.6	1.6	58	2.9	76	—
Essequibo Islands	6,701	121	10	1.6	0.1	16	5.0	22	—
West Coast Demerara	33,005	962	25	2.1	0.5	43	5.6	50	—
Demerara Estuary	39,290	731	48	1.7	0.8	45	17.6	64	—
East Coast Demerara	85,996	2,214	42.5	1.5	0.6	51	5.8	57	—
West Coast Berbice*	10,424	300	1.7	1.6	0.03	7.3	0.8	8	—
Berbice Estuary	10,592	501	65	2.2	1.5	55	13.6	74	—
Lower Canje	13,282	192	49	2.6	1.3	54	10.5	65	—
Corentyne Coast*	57,451	699	2	1.5	0.03	10	0.4	12	—
Urban Areas									
Georgetown	84,962								
Central Wards		350	2.8	1.5	0.04	4.2	0.3	6.6	—
Peripheral Wards		815	15.0	1.2	0.2	33	7.6	47	—
Suburbs		889	30	2.4	0.7	41	12.0	47	—
New Amsterdam		401	16	1.9	0.3	29	2.7	34	—
After DDT (1949–50)									
Rural Areas									
Essequibo Coast†	22,734	1,600	28.9	0.81	0.23	0.25	0.0	28.9	9
Essequibo Islands	6,701	686	12.5	0.76	0.09	0.00	0.0	12.5	0
West Coast Demerara	33,005	844	4.4	0.74	0.03	1.04	0.0	5.2	18
Demerara Estuary	39,290	1,100	3.0	0.92	0.02	0.40	0.0	3.2	6
East Coast Demerara	85,996	2,000	3.3	0.82	0.03	0.00	0.0	3.3	0
West Coast Berbice*	10,424	350	0.0	0.00	0.00	0.00	0.0	0.0	0
Berbice Estuary	10,592	575	5.0	0.74	0.03	0.34	0.0	0.0	6
Lower Canje	13,282	200	7.0	0.68	0.04	0.00	0.0	0.0	0
Corentyne Coast*	57,451	100	0.0	0.00	0.00	0.00	0.0	0.0	0
Urban Areas									
Georgetown	84,962								
Suburbs		863	0.7	0.50	0.003	0.65	0.0	1.4	15
New Amsterdam	12,305	250	0.8	0.50	0.004	0.00	0.0	0.8	0
All Districts	376,742	8,568	8.5	0.80	0.007	0.28	0.0	9.4	54

* Epidemic malaria only.

† The Essequibo Coast was the last district brought under control at the end of 1947. This was a hyperendemic and economically depressed area with a strong prevalence of East Indians in the population; large spleens were numerous.

Anopheles darlingi, formerly the prevailing house-frequenting anopheline, has completely disappeared from all treated areas in British Guiana, comprising some 280 miles of coastlands and estuary banks plus large areas of the interior. Constant search has not revealed a single mosquito of this species within the controlled area during

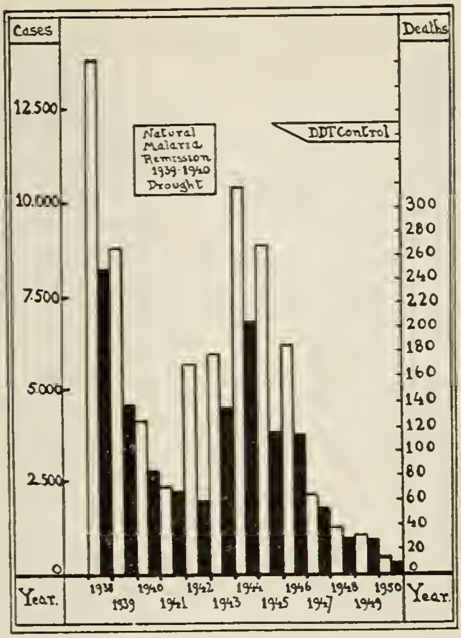

FIG. 2. Hospital admissions (white) and deaths (black) caused by malaria on the sugar plantations of the Colony, in a population of 75,000, from January 1938 to August 1950. In all cases the diagnosis was clinical only; allowance must be made for a considerable margin of error. The annual error throughout this series may be gauged by the results of the blood examination of 1,292 such cases during 1949 and 1950, after the establishment of DDT control; only four slides (0.31 per cent) were found positive.

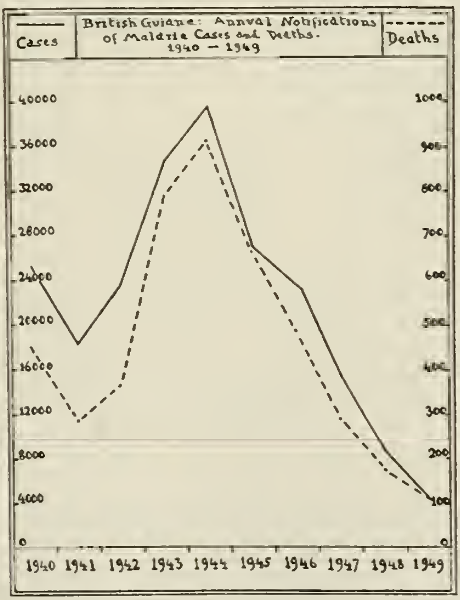

FIG. 3. Official weekly notifications of cases and deaths attributed to malaria in British Guiana from 1940 through 1949. The diagnosis was rarely confirmed microscopically, so that a considerable margin of error must be allowed.

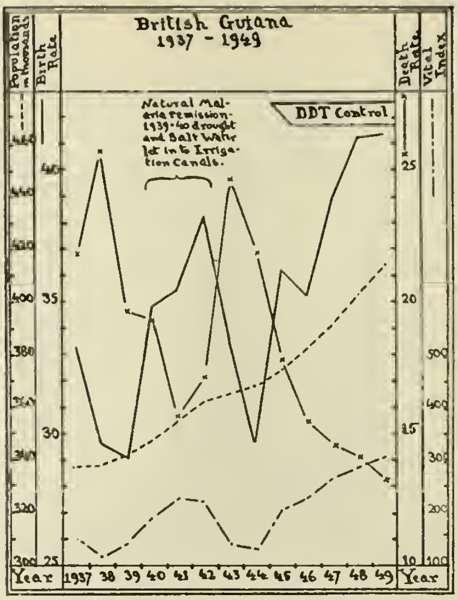

FIG. 4. Population, birth-rate, death-rate, and crude vital index trends from 1937 to 1949. A very exceptional natural malaria remission which occurred, as an effect of the 1939–40 drought, during the years 1940 to 1942, though on a smaller scale and only temporarily, caused identical modifications in the trend of vital statistics as those realised by DDT control. This is also clearly noticeable in figs. 2, 3, and 5.

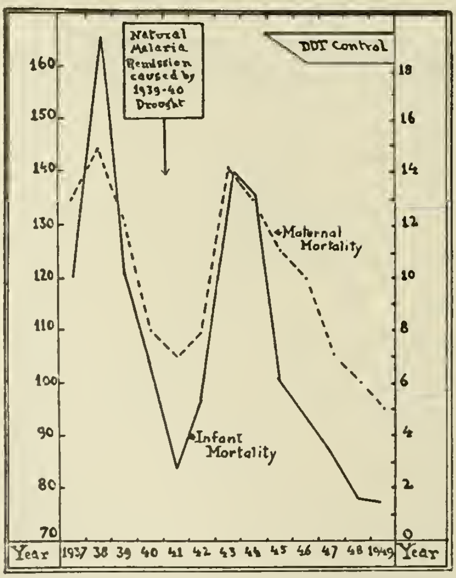

FIG. 5. Trends of annual infant and maternal mortality in the Colony from 1937 to 1949 inclusive. The fall in infant mortality (continuous line) was mainly due to reduction in deaths from prematurity and congenital debility, caused by malaria in the expectant mother. The improvement in maternal mortality (interrupted line) resulted mainly from the near elimination of megalocytic anaemia of pregnancy, formerly prevalent among East Indians in hyperendemic malaria districts; deficient diet, pregnancy and malaria appear to be closely related and complementary etiological factors in this disease.

the past three years. The effect of DDT on *A. darlingi* is so rapid and so drastic that there is no likelihood of resistant strains making their appearance. It is interesting to note that the incidence and distribution of *A. aquasalis*, *A. albitarsis*, and *A. triannulatus*, all zoophilic, non-domestic species, are completely unaffected by the DDT campaign; *A. aquasalis* and *A. albitarsis* larvae were collected in 20 per cent of nearly 10,000 potential breeding places examined during 1949 and 1950.

There can be no doubt that within the inhabited areas of British Guiana, *A. darlingi* has been eradicated. As regards malaria this term cannot yet be applied appropriately because a certain number of obviously residual infections still persist from the pre-DDT era; a very few cases have also occurred with the characteristics of more recent infections. The origin of these cannot always be established. Some may be relapses of old infections, others are new infections contracted outside or at

TABLE 5

British Guiana—vital statistics 1937–1949

YEAR	POPULATION	BIRTH RATE PER 1,000	DEATH RATE PER 1,000	CRUDE VITAL INDEX	INFANT MORTALITY PER 1,000 LIVE BIRTHS	MATERNAL MORTALITY PER 1,000 LIVE BIRTHS	MALARIA
1937	337,039	33.3	21.9	152	121	13	Average
1938	337,521	29.7	25.8	115	166	15	Endemic exacerbation and epidemics
1939	341,237	28.1	19.7	143	120	12	Average
1940	346,982	34.7	18.4	188	104	8	Natural remission caused by 1939–40 drought
1941	354,219	35.4	15.6	227	84	7	
1942	361,754	38.2	17.2	222	97	8	
1943	364,694	33.5	24.7	136	141	14	Epidemic
1944	367,204	28.6	21.9	130	136	13	Severe
1945	373,598	36.2	17.8	204	101	11	Average
1946	381,325	35.2	15.5	228	87	10	DDT
1947	390,857	38.9	14.6	266	87	7	DDT
1948	402,615	41.3	14.2	290	78	6	DDT
1949	414,331	41.4	13.3	312	77	5	DDT

the periphery of the controlled area, others might be new infections acquired within the area but transmitted by *A. aquasalis*. The great rarity of gametocyte carriers (none observed for the last three years), and the habits of *A. aquasalis* render the last hypothesis rather doubtful. In fact, one of the many results of the DDT campaign has been to demonstrate the negligible role of *A. aquasalis*, and of anophelines generally, other than *A. darlingi*, in the local transmission of malaria.

Though more time is necessary to formulate a final verdict on the ultimate effect of the campaign, it can be stated that both endemic and epidemic malaria have already disappeared from the Colony, and that typical clinical and parasitological cases of the disease have become so rare as to cause considerable excitement in medical circles when discovered.

A clinical diagnosis of malaria nowadays is only rarely confirmed by blood examination. The following figures give the best indication of the malaria situation in

British Guiana during the last two years. In a series of 11,240 thick blood films examined by the Mosquito Control Service Laboratory, only 28 were reported positive. With the exception of two slides, parasites were scarce and ring forms only

TABLE 6

British Guiana Sugar Estates—vital statistics*

	1943	1944	1945	1946	1947	1948	1949
East Coast Demerara—malaria hyperendemic							
Population	17,331	15,926	15,845	16,195	16,271	16,451	16,899
Birth Rate	24.1	27.7	40.8	36.5	41.7	46.5	52.6
Death Rate	21.4	20.0	13.6	12.2	13.1	11.3	9.6
Crude Vital Index	112	138	300	300	319	452	545
Infant Mortality	222.5	160.6	92.8	92.9	120.4	75.7	68.9
Demerara Estuary—malaria endemic to hyperendemic							
Population	11,592	10,935	10,723	11,474	11,567	12,599	13,256
Birth Rate	20.8	13.9	21.6	25.4	31.6	32.7	36.4
Death Rate	17.5	15.7	12.3	10.2	6.8	7.7	6.9
Crude Vital Index	119	88	176	249	463	424	525
Infant Mortality	289.2	296.0	145.9	116.4	79.2	109.2	107.6
West Coast Demerara—malaria endemic							
Population	13,713	13,176	12,875	13,011	13,567	13,923	14,592
Birth Rate	34.6	28.6	34.8	41.5	42.3	52.8	52.8
Death Rate	15.1	21.8	16.7	15.9	14.5	11.6	11.5
Crude Vital Index	119	88	176	249	463	424	459
Infant Mortality	289.2	296.0	145.9	116.4	79.2	109.2	71.3
Berbice River Estuary and Lower Canje Creek—malaria hyperendemic							
Population	9,216	9,290	9,396	9,474	9,344	9,457	9,573
Birth Rate	43.5	31.7	42.8	34.2	39.4	56.6	48.3
Death Rate	16.8	16.4	9.0	12.5	8.9	10.2	10.3
Crude Vital Index	258	193	473	272	549	552	467
Infant Mortality	109.7	101.7	64.6	101.8	43.3	63.4	71.2

* On all these sugar plantations malaria used to be severe, and hyperendemic in the majority; DDT operations were begun in 1946 and all estates were under control by the end of 1947. The change in vital statistics, following the eradication of *A. darlingi* is therefore even more spectacular than for the Colony as a whole, as the returns for the latter include urban populations and also refer to the eastern costal districts of Berbice which were free from endemic malaria. As usual, with small population groups, these sugar estate figures are not entirely accurate as they do not include births and deaths occurring off the plantations. This error, however, is uniformly distributed and does not affect the significance of the trends shown above.

were seen. It is likely that these presumed rings were artifacts, but we have recorded them as parasites, in order not to bias the judgment of our technicians. Of this series of slides 7,768 were collected in school surveys, 2,060 from infants born in

1949 and 1950 on formerly hyperendemic sugar estates*, and 1,412 from persons suffering from a malaria-like fever. In the latter group, 955 slides were examined in 1948, with 6.6 per cent reported positive, 799 in 1949, with 0.5 per cent positive, and of 493 examined up to the end of October 1950 none were reported positive.

It does not appear that any other factor besides DDT shared in bringing about this spectacular change in the local malaria situation. Progress has been gradual and consistent as the campaign advanced, despite the fact that during the past three years the rainfall has been exceptionally high and persistent, a factor favourable to *A. darlingi* production. In pre-DDT days such heavy precipitation would, in all probability, have been followed by a severe exacerbation of endemic malaria, and epidemic explosions in our usually healthy eastern coastland areas.

The *A. darlingi* eradication campaign in the inhabited areas of British Guiana presents certain features which differentiate it from most other eradication projects on which published information is available. British Guiana is a mainland country, apart from its seacoast, and has no boundaries so far as mosquitoes are concerned. Moreover, as I am always at pains to specify, our eradication campaign is limited strictly to inhabited areas where the control technique is based exclusively on house spraying. When the last house has been treated, our task is finished; where houses do not exist, no control measures have been applied. Beyond these last houses lie the vast uninhabited expanses of equatorial South America, which are still *terra incognita* as far as *A. darlingi* potentialities are concerned.

At the present stage of our knowledge, the possibility of reinvasion of controlled districts by *A. darlingi* offers serious implications; it is an eventuality which must not only be contemplated but expected. It should be emphasised that ideal conditions for *A. darlingi* breeding still exist throughout the inhabited area, as indicated by the present-day flourishing adult and larval population of *A. aquasalis*, *A. albitarsis*, and *A. triannulatus*, all former breeding associates of *A. darlingi*. In terms of a continental country, our project differs fundamentally from the island campaigns on Cyprus, Sardinia, and Mauritius.

In British Guiana *A. darlingi* is an autochthonous mosquito. Wherever we have dealt with it, be it on cultivated coastland, in dense forests, on open savannah, or on the Pakaraima plateau, it has been fought in its native habitat. Here again our project differs from the successful mosquito eradication campaigns conducted under continental conditions such as against *A. gambiae* in Brazil and the Sudan, and against *Aedes aegypti* in Brazil, where the mosquito enemy was an importee or a recent invader, possibly subsisting under not entirely congenial conditions. It is known in fact that the eradication of *Aedes aegypti* is a much more arduous proposition in Africa, its country of origin, than it is in this hemisphere. Another notable characteristic of our campaign which should be emphasized is that it has been conducted entirely with the new residual DDT technique, completely ignoring the hydrological problem and the aquatic phases of *A. darlingi*'s biological cycle. Residual spraying technique has been applied in its purest and simplest form.

At the present stage, when eradication has been successfully accomplished, we are

* Before DDT was introduced, an infant born on these estates generally acquired malaria within three months after birth.

confronted with the problem of making our conquest permanent. Must we continue the wholesale application of DDT indefinitely and on the same original pattern? How much of our initial costs can be written off as capital expenditure? What are our indefinitely recurring operational expenses likely to be?

Before these questions can be answered, even tentatively, it is necessary to examine briefly certain aspects in the biology of our vector species.

1. Does *A. darlingi* exist as a forest mosquito entirely unassociated with man? Considering the immensity of the field to be explored and the difficulties of carrying out investigations on an adequate scale and under satisfactory conditions, it is obvious that the significance of negative observations is extremely relative. On this point I have made the following notes: In the cultivated coastlands of British Guiana, before the introduction of DDT, *A. darlingi* appeared to be localised in or within one-half to three-quarters of a mile from the neighbourhood of settlements. This was true in spite of completely uniform and favourable breeding conditions and the presence of cattle. Frequently they reappeared, four or five miles farther inland, where an isolated watch house or pumping station occurred on the plantation's back-dam. In two instances this species has been found in the uninhabited forest districts of the interior, the first on the Rupununi River in the Kanuku Gorge and the other (Dr. C. R. Jones) on the Wenamu trail, which crosses the watershed between the upper Mazaruni and Cuyuni valleys from the headwaters of the Kamarang to the Wenamu River. In both instances the observation was made at an habitual forest camping site on well marked and ancient lines of Indian travel. It is evident that in such localities the association of *A. darlingi* with man can only be extremely precarious, and that its survival is conditional to its feeding on wild animals. Nevertheless, the question to be answered is whether its presence in these uninhabited forest regions is primary or secondary to the presence of man, even if this presence be only occasional and transient.

2. Migrations of *A. darlingi*. The eastern coastlands of British Guiana, extending for approximately 40 miles between estuaries of the Berbice and Corentyne Rivers, are naturally free from *A. darlingi*, and have an extremely mild malaria problem, possibly related to *A. aquasalis*. At long intervals in the past, during years of exceptionally high and prolonged summer rainfall, *A. darlingi* temporarily invaded this district from the Berbice estuary, causing severe epidemics. The last such epidemic was recorded in 1938, but the severe drought which followed in 1939 to 1940 caused *A. darlingi* to disappear. It has not been seen in this district during the past eleven years.

More interesting are two instances of malaria, transmitted by *A. darlingi* and recorded in certain districts of the interior that had been malaria-free for many years. Intelligent, educated ranchers from the Rupununi savannahs, familiar with the general clinical manifestations of malaria, were unanimous in denying the existence of endemic malaria on the savannahs up to the year 1930. It was said to have appeared suddenly around 1932 and spread rapidly whilst steadily assuming severe endemic form which persisted up to the advent of DDT spraying in 1947. On these savannahs, *A. albitarsis* occurs in great numbers during the rains, but in 1937 *A. darlingi* was found in the first collection obtained from the area. Subsequent

observations proved that this species was mainly localised along the forest-fringed rivers and lakes which intersect the open grasslands. The first outbreak of malaria in the Rupununi savannahs coincided with a period of greatly increased launch traffic, necessitated by the activities of an International Boundary Commission in the district between 1930 and 1935.

In October 1947 a severe epidemic of subtertian malaria broke out among the Patamona Indians in the southern portion of the Pakaraima plateau, on the watershed between the Potaro and the Ireng or Mahu Rivers. From the accounts of miners, who had long worked in this area, and from the acute clinical reactions presented by the patients, it appeared obvious that malaria was of very recent introduction, and that the population possessed no immunity. The main focus of infection was found to be a diamond placer mine in the heart of the region, providing the main working and trading centre for the Indians of the surrounding area. *Anopheles darlingi* was found in the houses, and larvae were collected from rain-flooded gravel pits at the mine, and in a stream which had been dammed to supply water. Indians usually travel with their whole family, so that most of the men, women, and children of the district had visited the mine and camped in its neighbourhood for periods varying from a few days to weeks or months. Thus it is not surprising that malaria, once introduced in this area, flared up all over the district even if we were not able to establish the presence of *A. darlingi* at any other point. The placer where *A. darlingi* had become well established is situated midway on the main Indian trail, approximately 60 miles long, which connects the upper Potaro River, above Kaieteur Falls, with the Ireng River. This trail runs for its greater part through forest; it also traverses rugged mountainous country ranging in altitude from 1,200 to 3,000 feet. The area through which it passes is well watered and has a very high rainfall; the ground waters are similar to those of the lower Potaro River, colourless and only slightly acid, the type most suitable for *A. darlingi.*

In both these observations, in the Rupununi savannahs and in the Pakaraima tableland, the appearance of malaria was sudden, and *A. darlingi* the vector. It is difficult to conceive that in either case *A. darlingi* could have pre-existed in these districts as a harmless mosquito, when one considers that numerous gametocyte carriers, infected in the heavily endemic lower valleys of the Essequibo and Potaro Rivers, were without doubt traversing both areas at all times. It appears much more rational to admit that *A. darlingi* was the actual invader.

These observations suggest that *A. darlingi* may travel along the routes of habitual human traffic, rapidly where the population is dense, and climatic and hydrological conditions favourable, as on our eastern coastlands in 1938, albeit slowly where the population is sparse and environmental conditions less suitable. It is conceivable that a year of drought, for instance, might set back progression by years or even decades. To reach the Patamona Indian country on the Pakaraima tableland, from its habitual haunts in the gold mining areas of the lower Potaro River, *A. darlingi* would have to traverse some 100 miles of uninhabited but frequently travelled river banks and forest trails and overcome such a formidable natural barrier as the great Pakaraima escarpment, rising vertically some 900 feet above the lower Potaro valley. In the course of such migrations, if my surmise is correct, the progress of *A. darlingi*

is unobtrusive. When it reaches populated areas offering favourable environmental conditions and an abundance of human hosts, the mosquito multiplies and the stage is set for an epidemic explosion of malaria.

There is no doubt that in sparsely inhabited districts *A. darlingi* feeds on animals quite readily; this is evidently a *sine quo non* for its survival. In the Rupununi region this species was collected in large numbers on horses in the open, an experience which could not be duplicated in the well populated coastlands.

It is considered that these epidemic episodes of malaria from the Rupununi savannahs and the upper Potaro River, and the two observations of *A. darlingi* in uninhabited forests may have represented glimpses of different phases of one and the same process, for both factors fit into the general scheme of close association between *A. darlingi* and man. Not only is this association everywhere obvious, but it has been spectacularly proved by the effects of residual DDT applied exclusively to the interior of houses. This is one point of fundamental importance which emerges from all our observations whether conducted under varied environmental conditions on the coast, in old established endemic areas of the forested lowlands, on the savannahs, or in localities of recently introduced endemic or epidemic malaria in the least accessible parts of the interior: *A. darlingi* always and everywhere shows sufficient specific attraction to man and his habitation, *sensu latiore*, to be fully vulnerable to DDT as a residual spray applied to the interior of houses. In the Rupununi savannahs DDT applied to widely scattered houses has caused *A. darlingi* to disappear selectively. In the previously heavily infested and intensely malarial Potaro gold-mining district, there were about 350 habitations, most of them bush shacks, strung out in small groups over 18 miles of forest trail. Spraying the interiors every six months since August 1946 has been sufficient to clean up malaria in the whole of this ill-famed region.

3. Natural factors limiting the distribution of *A. darlingi*. In 1938 we recorded three natural factors which are unfavourable to *A. darlingi* production and tend to limit its distribution and incidence:

a. *Desiccating power of the atmosphere.* This is a function of atmospheric temperature, humidity, and wind velocity. In this uniform equatorial climate its variations are mainly dependent on wind velocity and ventilation. *Anopheles darlingi*, primarily an inland forest mosquito, is highly susceptible to desiccation, and is not found on the wind-swept open savannahs, whether on the coast or in the interior, but it may make its appearance in these situations during seasons of unusual rainfall, reduced wind velocity and increased humidity, or if ecological conditions are altered by the planting of trees or special crops.

b. *Sodium chloride titre of ground waters. Anopheles darlingi* is rarely found in waters containing over 150 milligrams of NaCl per litre.

c. *Soil and water hydrogen-ion concentration.* This factor has frequently been discussed in relation to mosquito biology. In the equatorial rainforest of the lime-deficient Guiana region acid waters prevail, and low pH values (3.5–4.0–4.5) are characteristic of waters originating from certain local geological formations and soils. In the interior there is the sedimentary White

Sand Series of the peneplain and the Kaieteurian Sandstone formation of the Pakaraima highlands; on the coast, peaty "Pegasse" soils form the backlands of the alluvial coastal plain. Throughout the Guianas acid, soft waters, deeply coloured by organic matter in colloidal suspension, alternate with the less acid, colourless or opalescent waters which are characteristic of the red, lateritic loams of the more ancient inland formations, giving rise to the innumerable Rio Negros and Rio Brancos, respectively, scattered all over this region of equatorial South America. *Anopheles darlingi* does not breed in waters with a pH below 4.5; its optimum appears to be between pH 5.5 and neutrality.

On the inhabited coastlands of British Guiana all three of these factors affect the epidemiology of malaria. Atmospheric, salt soil, and brackish water factors are clearly operative in the Berbice coastlands, so that here malaria is typically epidemic, and is transmitted at long intervals by *A. darlingi*, which comes in from the estuary of the Berbice River during years of exceptionally high summer rainfall.

Acid "Pergasse" or peaty soils are found all along the coast four or five miles inland; they originate from the accumulation of decaying vegetable matter in fresh water marshes lying behind the seashore or river banks and estuaries. It is on the narrow, fertile, coastal strip of clay and loamy clay soils between the sea and the "Pegasse" soils that all the cultivated land and settlements are situated. In the surface waters of these soils, of relatively low acidity, *A. darlingi* finds its optimum medium; its larvae are not found in the acid waters of the "Pegasse" belt. Hence the unfortunate coincidence that man, *A. darlingi*, and hyperendemic malaria are all localised on the narrow, fertile, coastal strip and on the banks of the river estuaries.

An unusual meteorological deviation occurred in 1939 and 1940, that affected surface waters throughout the coastlands up to the end of 1941, gave an opportunity to study the effect of some of these factors on *A. darlingi* under conditions which were very nearly as clean-cut as those of a laboratory experiment. In 1939 the autumn rains failed entirely and a severe drought prevailed through 1940. The water conservancies dried up and to make water transportation possible on the sugar estates it was necessary to introduce salt water into the irrigation network. High sodium chloride titres prevailed in all the canals up to the middle of 1941 and *A. darlingi* practically disappeared from the coastlands. With the gradual return of a normal hydrological situation during the latter half of 1941, it was possible to follow step by step the progressive reinvasion of the coastlands by *A. darlingi*. It took nearly two years for this mosquito to complete the occupation of the coastlands lying between the Demerara and Essequibo River estuaries. Reinvasion proceeded gradually from south to north along the left bank of the Demerara River to the sea, then progressed gradually westward from village to village along the coastal road (see figure 6). There was no evidence of direct invasion from the interior through the barrier of acid "Pegasse" soils lying behind the coastal settlements. These natural control factors, as they apply to *A. darlingi*, have been known here for many years, and their effects have been amply confirmed through a very large series of field observations and by laboratory experiments; but it was only after the advent of DDT that their practical potentialities became apparent.

In British Guiana we are at present directing our malaria control activities on a

plan which aims to integrate existing natural barriers against *A. darlingi* with systematic DDT "strategic" spraying of only those houses situated along the forced passages through which *A. darlingi* would have to travel in order to reach the coastlands. Routine spraying will thus be limited to houses on the banks of the rivers and their estuaries.

On the east Demerara coastlands, owing to the less defined "Pegasse" soil barrier, we propose, as a provisional measure, to spray only a fringe of houses on the landward side of settlements, using the barrier principle successful in Georgetown and New Amsterdam. Whether this operation will be continued depends on the general results of this new technique and on further field observations. The population involved amounts to over 90,000, but the houses of only one-third of this number will be treated.

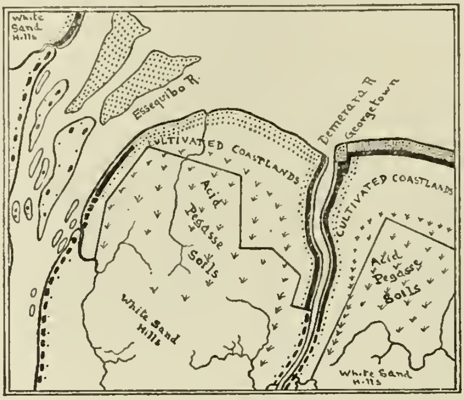

FIG. 6. Integration of a natural barrier against *A. darlingi* with strategically located "blocks" of DDT-sprayed houses: Acid "Pegasse" soils, unsuitable for *A. darlingi* production lie back of the densely populated coastlands, formerly subject to hyperendemic malaria. *A. darlingi* has been eradicated throughout the coastal area; reinvasion from the interior could only occur along the river banks where soil and water conditions are favourable to this mosquito. Permanent DDT spraying operations may be restricted to these strategic localities, which are outlined in black on the map. Dots indicate distribution and density of population.

On the eastern Berbice coastlands, which are subject to occasional *A. darlingi* invasion and consequent malaria epidemics, it is believed that continued systematic DDT spraying on the Berbice and Corentyne estuaries will be an adequate safeguard. The houses of 50,000 inhabitants of this part of the coastlands will not be sprayed routinely. In fact, it is estimated that at the present stage control can be maintained throughout the densely inhabited coastlands of British Guiana by the routine spraying of the houses of one-fourth to one-third of the population, with an estimated reduction in operational costs varying from 60 to 75 per cent of previous expenditure. The question of the interval at which spraying should be repeated, in this operational zone, is still under investigation; at present we are spraying once every 18 months.

The neighbouring country of Surinam gives a very good example of how strategic

control by "road block" could be employed to safeguard an area liable to invasion by *A. darlingi*. The more densely inhabited coastal plain (population approximately 200,000) is backed, at a distance varying from five to twenty-five miles from the sea, by a narrow strip of white quartz sand hills of uniform and low altitude. This formation, known locally as the "Savannah", runs parallel to the coast and varies in depth from three miles in the east, on the French Guiana frontier, to 22 miles along the right bank of the Corentyne River. This formation is identical with, and represents an eastern extension of our White Sand series, and is characterised by the same type of intensely acid, humus-stained surface waters which are quite unsuitable for *A. darlingi* production. Apparently this formation has proved an efficient barrier against *A. darlingi*, which is found farther south in the "Bush", where lateritic loams and less acid waters prevail. At both ends of this "Savannah" barrier, *A. darlingi* has occasionally broken through: in the west, at Nickerie on the Corentyne River,

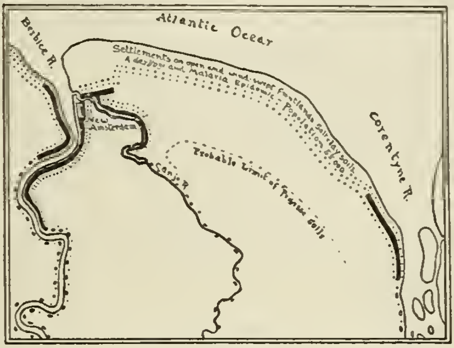

FIG. 7. The eastern Berbice coastlands, owing to the brackish nature of local soils and waters, were only occasionally subject to *A. darlingi* invasion from the Berbice estuary. During years of exceptionally high rainfall, severe epidemics of malaria occurred, the last in 1938. *A. darlingi* has been eliminated from the estuaries east and west of these coastlands, and it is expected that systematically continued DDT operations limited to the banks of the Berbice and Corentyne Rivers (areas marked in black) will be sufficient to safeguard this well-populated coastal area.

serious malaria outbreaks were recorded repeatedly some 25 years ago when the balata industry flourished on that river. In 1939 Swellengrebel and Van der Kuyp found *A. darlingi* and severe endemic malaria on the coastal plain north of the narrow eastern limit of the savannah on the Morawyne River. On the coastlands of Surinam, agriculture is less developed than in British Guiana and irrigation is a *sine qua non* for the proper use of the land. In British Guiana, under entirely comparable conditions, irrigation, *A. darlingi*, and severe endemic malaria are nearly synonymous.

The "Savannah" is traversed from south to north by a number of rivers in an area only sparsely inhabited. A railroad and a highway connect the capital, Paramaribo, with its inland airport and the interior. These are the only possible avenues through which *A. darlingi* can reach the coastal plain. There is every reason to believe that DDT "road-blocks", established along these routes by spraying the

few hundreds of houses which border the rivers, the railway, and the road to the airport, would completely integrate the excellent natural defences of this area.

The foregoing examples will suffice to illustrate the technique which we consider should now be adopted more universally. It must be said that detailed knowledge of *A. darlingi* and its local ecology is a fundamental requisite for the intelligent application of strategic DDT control. At the same time it must be remembered that wholesale DDT application puts a fullstop to epidemiological investigations. Accordingly, it may be a sound policy as regards long-term malaria control, in areas where adequate data are not available, to postpone operations in a few typical localities, for the purpose of collecting more accurate information on the subject of natural factors which tend to limit the incidence and spread of *A. darlingi.*

From my own experience, under the varying environmental conditions described previously, and from reports in the literature available from neighbouring countries, it appears that *A. darlingi*, within its very wide area of distribution, tends to be "patchy" and irregular in its occurrence. This fact alone seems to indicate that favourable conditions for its abundant production are restricted in positive or negative relation to certain local and seasonal factors. It would seem reasonable to conclude, therefore, that the principle of identifying these local "anti-factors", and basing strategic control upon them, may find wide application throughout equatorial South America.

REFERENCE

Giglioli, G. 1948. Malaria, filariasis, and yellow fever in British Guiana. The Daily Chronicle Ltd., Georgetown, British Guiana.

RESUMEN

El 90 porciento de los habitantes de la Guiana Británica vive en una faja de terreno de 5 a 10 millas de ancho a lo largo de una costa de 280 millas. Los demás habitantes están dispersados por el interior. Agricultura de cultivo húmedo en el terreno de la costa ofrece condiciones ideales para la crianza de mosquitos anofelinos y por lo tanto malaria llegó a proporciones endémicas y epidémicas. Métodos clásicos de control de larvas no fueron posibles.

Por medio de estudios empezados en el 1932 se había establecido que *Anófeles darlingi* era prácticamente el único transmisor de malaria en el país porque éste se asociaba muy estrechamente con el hombre en sus hábitos de alimentación y crianza. *Anófeles aquasalis*, *A. albimanus*, y *A. triannulatus*, aunque comunes, son zoofílicos y probablemente actúan únicamente como vectores secundarios.

El programa de tratamiento de hogares con DDT empezó en 1945 en áreas experimentales limitadas que fueron gradualmente extendidas hasta que en 1950 se ha estimado que 98 porciento de los habitantes han sido protegidos por el programa. El insecticida se aplicó a superficies de madera en una solución de kerosina al 5 porciento; a superficies absorbentes en una suspensión al 10 porciento de polvo humedecible conteniendo DDT al 50 porciento. El tratamiento ideal fué de 150 mgm. por pie cuadrado. En áreas rurales todas las casas fueron rociadas; en las ciudades solamente aquellas situadas en áreas periféricas y suburbanas. Hoy día, el intervalo

entre rociadas es de 18 meses. El costo per capita en 1950 fué aproximadamente $0.20 (E.E.U.U.).

Immediatamente después de ser rociadas todas las casas en un área, capturas de *Anófeles darlingi* en éstas resultaron negativas y por dos a cuatro semanas las larvas de esta especie desaparecieron del área sin causar ningún efecto en las otras especies anofelinas. Como resultado *Anófeles darlingi* ha desaparecido de todas las áreas tratadas y no se ha encontrado en los últimos tres años. Excepto por algunos casos restantes, ya sean recaídas de infecciones viejas o nuevos casos adquiridos en áreas periféricas, la malaria ha desaparecido. Es improbable que otro factor aparte de DDT haya sido responsable de la desaparición de malaria ya que las condiciones del tiempo han sido ideales para su transmisión.

El programa de rociadas futuras se basará en las siguientes consideraciones: (1) *Anófeles darlingi* puede existir precariamente en áreas donde el hombre es raro o transeúnte; (2) El mosquito puede invadir de áreas periféricas, la rapidez de invasión estando directamente relacionada a la densidad de la población humana y las condiciones meteorológicas, (3) Adultos de *A. darlingi* no pueden resistir la sequedad; las larvas agua salina o ácida (sal más de 150 mgm./litro; pH menos de 4.5). Existe una barrera natural de agua ácida de extensión variable entre la costa y el interior. Las probables rutas de invasión por *A. darlingi* son limitadas a ríos y otros tránsitos usados por el hombre. Rociadas futuras serán limitadas a áreas periféricas especialmente a lo largo de las rutas de más probable invasión. Se espera que con este método se reduzcan los gastos de control por dos tercios.

NATION-WIDE MALARIA ERADICATION PROJECTS IN THE AMERICAS

Dr. Russell: We are keenly disappointed that owing to circumstances which could not be avoided or foreseen, it has been impossible for Dr. Mario Pinotti to come to Savannah. Since 1942 Dr. Pinotti has been Director of the National Malaria Service of Brazil and in this position he has planned and put into effect a huge but practical malaria eradication campaign. Those of you who know Dr. Pinotti are aware of his vivid personality, keen intellect, and outstanding administrative abilities. Last year I had the pleasure of spending several weeks in Brazil and I was tremendously impressed by the scope and practicality of Dr. Pinotti's malaria eradication scheme. I regret that he cannot present his paper in person, but it will be printed in the symposium number of the Journal.

Fortunately, Dr. Pinotti sent me a resume of his paper and, on the basis of this, an account of the Brazilian project will be presented to you by my colleague, Dr. Henry Kumm, who for several years past has represented the International Health Division of The Rockefeller Foundation in Brazil and who is also an outstanding malariologist. I shall never forget how efficiently in 1944 soon after the Allied Forces entered Rome, Dr. Kumm tackled the enormously difficult problem of malaria control in the Roman Campagna. Largely through Dr. Kumm's efforts this area was brought under control remarkably soon and this work served as one more of the demonstrations of the usefulness of DDT residual spraying. Dr. Kumm has often been consulted in regard to developments in the Brazilian project and is well qualified to discuss it.—Dr. Kumm.

IV. THE NATION-WIDE MALARIA ERADICATION PROGRAM IN BRAZIL

MARIO PINOTTI*

The first attempts to control malaria in Brazil were made at the beginning of this century. In addition to the work of Oswaldo Cruz, Carlos Chagas, and others, we would like to mention the studies in the coastal lowlands of the State of Rio de Janeiro, which we carried out under the direction of Mark Boyd, and a memorable campaign in the Northeastern states, which resulted in the eradication of *Anopheles gambiae* from Brazil (Soper and Wilson, 1943).

When the National Malaria Service was created in 1941 it undertook the task of organizing, orienting and putting into effect malaria control all over this country. Since its foundation the service has expanded greatly, and its development during the last decade will be the subject of this paper. For the past year the National Malaria Service has been responsible for malaria control throughout Brazil, except for the State of São Paulo, in which the National organization restricts its activities to certain Federal projects such as railways, naval, air, and military bases.

Brazil covers a total area of 8,516,037 square kilometers or approximately 3,385,000 square miles, which represents 47.3 per cent of the total area of South America. It can be subdivided into five major regions as shown in figure 1, namely the Northern, Northeastern, Eastern, Southern, and Central Western zones.

According to the Brazilian Institute of Geography and Statistics, 40.83 per cent of the total area of Brazil is located at altitudes varying from 0 to 200 meters, 44.57

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per cent lies between 201 and 600 meters, while only 14.60 per cent of the country consists of regions situated 600 meters or more above sea level.

A census taken on September 1st, 1940, showed the population of Brazil to be 41,236,315. On December 31st, 1948, the Brazilian Institute of Geography and Statistics estimated the population at 48,900,000.

Generally speaking the country shows three types of climate: equatorial, as characterized by the Amazon region, with its hot and humid climate and abundant rains; tropical, less humid than the equatorial climate, with variable amounts of

FIG. 1. Regional and administrative divisions of Brazil, showing the areas of the principal hydrographic basins.

rainfall; and subtropical or temperate climate as found in Southern Brazil and in some of the mountainous zones. Seasonal variations in rainfall, relative humidity, and temperature in various regions of this country are shown in figure 2.

CHARACTERISTICS OF MALARIA AND ITS PRINCIPAL VECTORS IN BRAZIL

Malaria is present to a greater or lesser degree in all of the twenty States, in the Federal District and in the four Federal Territories. In certain States and Federal Territories such as Amazonas, Amapá, Guaporé and Maranhão, malaria is found everywhere. In others, such as Minas Gerais, São Paulo and the State of Rio de

Janeiro, the disease is encountered in most of the counties, but some of them are entirely free of malaria. In the States of Rio Grande do Sul and Ceará, on the other hand, malaria is present in only a few counties. According to data collected in 1948 by the National Malaria Service this disease was found in about 65 per cent of the 1,780 counties into which this Republic was then divided.

Endemic malaria rates vary enormously from county to county, and in certain regions the disease has appeared at times in epidemic form. Within individual municipios* parasite rates may likewise differ widely from one small area to another. It has been estimated that at least 17 million people were exposed to malaria in its

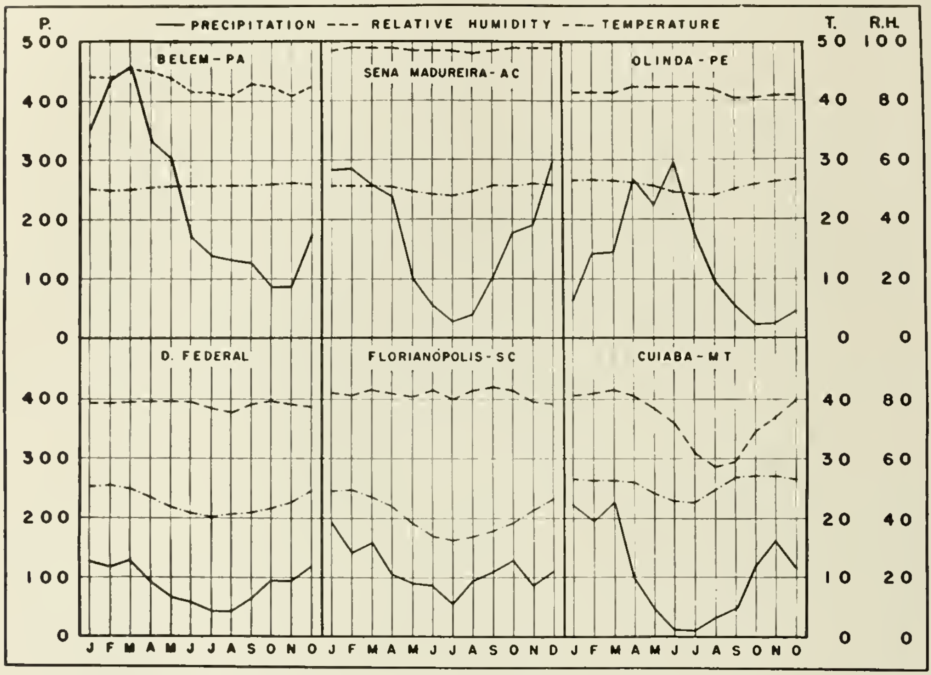

FIG. 2. Meteorological characteristics of various regions of Brazil. Belem and Sena Madureira (Northern Region); Olinda (Northeastern Region); Federal District (Eastern Region); Florianópolis (Southern Region); and Cuiabá (Central Western Region); rainfall in mm.; temperature in degrees centigrade.

endemic or epidemic form during the year 1940, or approximately 70 per cent of all of the inhabitants of the malarious regions of Brazil.

The principal vectors are *Anopheles* (*N.*) *darlingi*, *A.* (*N.*) *aquasalis* (*A. tarsimaculatus*), *A.* (*N.*) *albitarsis*, *A* (*K.*) *cruzii* and *A.* (*K.*) *bellator*. The first of these is undoubtedly responsible for most of the malaria which exists in this country, particularly in the interior. On the other hand, the zone where malaria is transmitted by anophelines of the subgenus *Kerteszia* is limited to 40 thousand square kilometers located in Southern Brazil.

* A municipio corresponds to a small U. S. county.

Anopheles aquasalis is encountered along the sea coast from the extreme north of the Republic to the municipio of Iguape in the State of São Paulo. In certain zones *A. darlingi* or *A. albitarsis*, or both, may be found simultaneously with *A. aquasalis*. On the basis of data collected during the 1940 census it has been estimated that the total population in those counties where malaria is transmitted by the *Kerteszia* species, is in the neighborhood of one million. However, in the interior of Brazil where malaria is transmitted only by *A. darlingi* the population is approximately 17 million.

The exact importance of *A. albitarsis* as a malaria vector has not yet been fully determined. It is, however, considered to be the only vector in certain restricted areas such as Salvador (Bahia), Iguape (São Paulo) (Correa *et al.*, 1950) and in Camaratuba, Paraíba, and Monte Alegre in Pará (Deane *et al.*, 1946).

During the three-year period from 1947 to 1949 inclusive, 114,158 persons were examined for splenic enlargement, and blood samples were collected from a total of 211,654 persons in order to obtain blood parasite indices. During these same studies, 356,514 anopheline larvae and adults were captured and identified. These surveys were carried out in as many localities as possible, and especially in areas for which no data were available concerning the prevalence of malaria or about the anopheline vectors. Although the number of persons examined was not as large as we should have liked, the data collected gave indications about the areas of high or low endemicity, and at the same time this information can serve as a basis for evaluating results of the house spraying program with DDT which was started soon afterwards.

Spleen indices in general were higher in areas where *A. darlingi* was responsible for the transmission of the disease, whether alone or in combination with *A. aquasalis* and *A. albitarsis*, than in areas where *A. aquasalis* was found alone or together with *A. albitarsis*. The spleen indices in the zone where malaria is carried by the *Kerteszia* species were quite similar to those found in the areas where *A. darlingi* is the vector. According to the data collected during these surveys, the highest malaria incidence was found in the São Francisco River valley, in the coastal lowlands of the State of Rio de Janeiro, and in certain other areas situated along the seacoast of various states, such as Bahia, Maranhão and Santa Catarina. In the areas of the Paraná Basin, the States of Minas Gerais, Goiás and southern Mato Grosso, endemic malaria generally showed a low incidence and was absent from the cities and smaller towns. Severe endemic foci were found, however, in the rural zones along the rivers and streams.

This paper does not touch upon the biology of the Brazilian malaria vectors, since this subject has already been discussed in various publications. In a recent paper Pinotti (1950) pointed out that the DDT house spraying program in Brazil is based upon the biology of the principal mosquito vectors because, although the percentage of certain species found inside houses is not very high, nevertheless most of the malaria transmitted by them is contracted indoors. In zones where malaria is carried by *A. darlingi*, *A. aquasalis*, and *A. albitarsis*, a large scale DDT house spraying program was started in 1947, and a similar project was initiated in the *Kerteszia* zone between 1948 and 1949. Preliminary experiments carried out by Bustamante

and Ferreira (1949) had already shown that this technique gave satisfactory results in areas of bromeliad malaria.

It is pertinent here to refer to the frequency with which *A. darlingi* has been captured outside houses in the central plateau, a finding which was reported by Bustamante, *et al.*, (1949). Recently, Bustamante and Guedes (1950) showed that this mosquito could be captured in large numbers in a "Shannon dawn trap" located at Engenheiro Dolabela in the State of Minas Gerais. In that particular locality

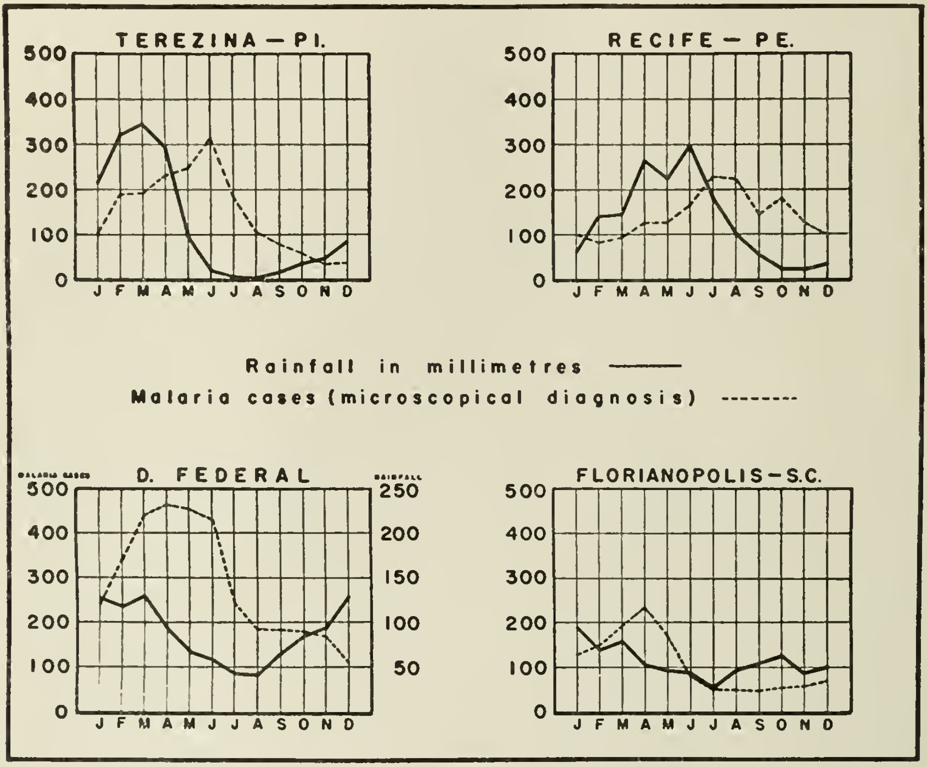

FIG. 3. Seasonal prevalence of malaria in Brazil based on the number of cases confirmed by microscopic examination of the blood (averages during the period from 1945 to 1948 inclusive) and its relation to rainfall. Terezina and Recife (Northeastern Region); Federal District (Eastern Region), and Florianópolis (Southern Region).

numerous specimens of *A. darlingi* were found resting on the outside walls of houses that had been sprayed inside with DDT (Bustamante *et al.*, 1950).

Seasonal variations in malaria are of prime importance in determining the correct interval of time between successive DDT house sprayings. In Brazil this period is influenced more by rainfall than by the characteristics of the vector species of anophelines. It has been found that in the Northern, Eastern, Northeastern, and Central Western regions of Brazil, some transmission occurs at all times throughout the year, though occasionally it may be interrupted during brief periods only.

Figure 3 shows that in Terezina (Piauí), Recife (Pernambuco), Florianópolis (Santa Catarina), and in the Federal District, the curve of malaria incidence follows that of rainfall with a lag of about two months. Only in southern Brazil in areas of the States of São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul, where mean temperatures during the cold months are below 17°C. (62°F.), does temperature itself actually influence the seasonal occurrence of the disease.

Malaria epidemics caused by *A. darlingi* have occurred in the States of Bahia, Goiás, Mato Grosso, Minas Gerais, Paraná, São Paulo, and in the Amazon Valley. There are records of five epidemics in the State of Paraná, in 1917, 1924, 1932–34, 1940, and 1945. During the last of these 19,931 persons received antimalarial treatment. The 1940 epidemic was much more severe than that in 1945. In northern Paraná, *A. darlingi* becomes very rare and in certain regions disappears completely during inter-epidemic periods. Reinvasion takes place from the north to the south

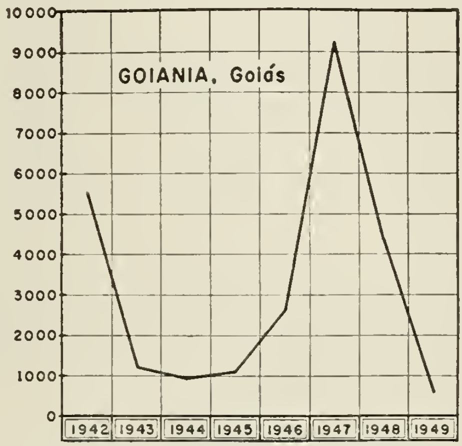

FIG. 4. Malaria morbidity rate per 100,000 inhabitants for Goiânia (Goiás), based on cases of malaria confirmed by microscopic examination of the blood.

along the valleys of the tributaries of the Paraná and Paranapanema rivers. It is possible that the energetic campaign of house sprayings with DDT which was carried out during 1950 prevented another malaria epidemic in northern Paraná, since *A. darlingi* has been found in several places within this area and, in the beginning of the year, there were a few overt cases of the disease.

Figure 4 gives the malaria morbidity rate for Goiânia, Goiás, based upon the number of cases confirmed by examination of blood samples during the period from 1942 to 1949 inclusive. These data and those from northern Paraná suggest that in these regions of *A. darlingi*-transmitted malaria, the disease recurs in epidemic form at intervals of five to seven years.

Occasional epidemics have been observed in the northeastern states, where malaria is carried by *A. aquasalis*, and in the valley of the Rio Uruguay, a region in which *A. albitarsis* is under suspicion.

MALARIA CONTROL PROGRAM FROM 1941 TO 1946

From its initial organization until 1946, measures employed by the National Malaria Service were largely restricted to campaigns directed against the aquatic phases of the vectors. These procedures consisted of drainage, application of larvicides, and manual removal and destruction of bromeliads. The two first methods were used against species of the subgenus *Nyssorhynchus*, namely *A. darlingi*, *A. albitarsis*, and *A. aquasalis*, while the third method was used against species of the subgenus *Kerteszia*. During this same period insecticides containing pyrethrum were employed occasionally for spraying houses, to protect troops stationed at military bases during the second World War.

TABLE 1

Antimalarial engineering projects carried out by the national malaria service during the five-year period from 1942 to 1946 inclusive

YEAR	DRAINAGE DITCHES		SUBSOIL DRAINS (METERS)	FILLS (CUBIC METERS)
	Constructed (meters)	Lined (meters)		
1942	423,237	22,392	63,692	333,672
1943	392,046	105,014	40,877	355,734
1944	220,745	20,010	21,223	400,979
1945	115,795	18,880	15,528	319,357
1946	100,751	83,373	12,605	394,309

TABLE 2

Amounts of larvicide used during the five-year period from 1942 to 1946 inclusive

YEAR	PARIS GREEN (KILOS)	PETROLEUM (KILOS)
1942	23,650	92,552
1943	28,495	79,512
1944	27,208	110,823
1945	27,513	153,233
1946	33,442	190,629

In order to reduce maintenance costs, many permanent drainage channels were lined with cement or stone, and wherever possible hydraulic fills were made. Table 1 indicates the extent of these projects.

The application of larvicides, especially Paris green, was another measure employed in the campaign against the vector species of the subgenus *Nyssorhynchus*. The amounts used are summarized in Table 2.

Drainage projects, as well as the application of larvicides, were feasible only in the State capitals and principal cities of this country. In rural zones free distribution of specific drugs was the best means available to lessen the sufferings of the population exposed to malaria.

In 1945 the National Malaria Service began experiments with DDT at Mangabeira in the State of Paraíba, at the Ipitanga air base in the state of Bahia, and in twelve other small localities. A total of 2,673 houses was sprayed in that year. In view of

the favorable results obtained from the initial experiments, DDT was employed during 1946 for the treatment of 6,419 houses in 50 small localities situated in various states. Excellent results were obtained against malaria transmitted by *A. darlingi* at Engenheiro Dolabela (Minas Gerais), as well as in the control of *A. aquasalis* at Mangabeira (Paraíba), and of *A. albitarsis* at the Ipitanga air base (Bahia). During 1947, therefore, the Service made arrangements to obtain much larger amounts of DDT, and since then the use of this insecticide has increased enormously, so that it has now completely superseded all previous antilarval measures.

Before 1945 the principal means of controlling bromeliad malaria in southern Brazil was the manual removal and subsequent destruction of all bromeliads found growing in the more densely populated areas. This method was highly successful in Florianópolis, where terrestrial bromeliads predominated, but it did not produce equally encouraging results in other localities, which were surrounded by forest with abundant arboreal bromeliads. During 1946, therefore, the National Malaria Service

TABLE 3

The campaign against the vectors of the subgenus kerteszia, area of forest cut down and number of bromeliads destroyed to 1949

YEAR	AREA OF FOREST DESTROYED (SQUARE METERS)	NUMBER OF BROMELIADS DESTROYED (EST.)*
1943	—	4,989,856
1944	—	27,308,945
1945	—	30,408,910
1946	5,181,603	19,737,558
1947	17,625,206	13,459,309
1948	10,318,570	9,137,366
1949	5,504,060	9,542,677
Totals..............................	38,629,439†	114,584,621

* Including those growing in the areas where forest was cut down.

† Approximately 95.5 acres.

started to cut down all forests surrounding the larger towns in the critical area of the State of Santa Catarina. This program has been discussed by Ferreira (1946), Pinotti *et al.*, (1946), and Ferreira and Rachou (1949). The area of forest cut down and the number of bromeliads eliminated is summarized in Table 3.

The results obtained will be discussed later. Manual removal of bromeliads and deforestation have solved the urban malaria problem in several important towns, but these measures are impractical for the control of *Kerteszia*-transmitted malaria in rural areas.

A few experiments were made to study the effect of spraying DDT and benzene hexachloride over wooded areas by means of a helicopter in order to destroy the vectors of the subgenus *Kerteszia*. The preliminary results of these experiments were published by Bustamante *et al.*, (1949), Ferreira *et al.*, (1949), and by Rachou *et al.*, (1949). A big reduction in the *Kerteszia* population was observed in the treated areas, but reinfestation took place rapidly, particularly if spraying was done during the period of heavy rains.

DEVELOPMENT OF THE DDT HOUSE SPRAYING PROGRAM SINCE 1947

The first extensive DDT house spraying programs carried out by the National Malaria Service were started early in 1947. In the São Francisco river valley and in the coastal lowlands of the State of Rio de Janeiro 41,339 and 130,419 houses, respectively, were sprayed. Those areas were selected not on a basis of high malaria incidence but rather because adequate financial resources were made available to the Service for carrying out those programs. Suitable contracts were signed by the São Francisco Valley authorities and by the Government of the State of Rio de Janeiro. The São Francisco Valley program included localities in the States of Bahia, Minas Gerais, Pernambuco, Alagoas, and Sergipe.

During 1948 and 1949 the National Malaria Service rapidly extended its program so that by 1950 it was covering most of the malarious regions of Brazil. The growth of the Service during the five year period from 1945 to 1949 inclusive is shown in Table 4.

TABLE 4

Expansion of the program of the national malaria service of Brazil from 1945 to 1949

YEAR	DDT (TECH. GRADE) USED (KILOS)	NUMBER OF HOUSES SPRAYED WITH DDT	NUMBER OF LOCALITIES WORKED*	TOTAL POPULATION OF COUNTIES WHERE WORK WAS DONE
1945		2,673	167	5,572,014
1946	3,500	6,419	221	4,154,721
1947	94,000	186,189	2,124	6,933,399
1948	526,736	968,611	6,782	11,744,847
1949	1,249,340	2,364,279	33,473	17,763,179

* Following the advent of DDT, larvicidal methods, except for the removal of bromeliads, were largely superseded by house spraying with insecticides.

The areas of the country which were protected by antilarval measures in 1945 and by house spraying with residual insecticides in 1949 are shown in figures 5 and 6. It should be noted that when control measures were aimed at the larval phase of the vectors, the population in the counties worked was only partially protected, since these procedures were carried out only in the principal cities and their immediate environs. From 1947 onwards the majority of the inhabitants of each municipality treated have been protected with DDT.

The curves presented in figure 3 show that in most parts of Brazil the annual transmission season lasts for six to eight months or more. For that reason two sprayings with DDT per year should generally be necessary in most regions. Our initial plan had forseen this procedure and the first extensive house spraying programs in the São Francisco valley and in the coastal lowlands of the State of Rio de Janeiro are still being carried out on a basis of two sprayings per year. Three sprayings were made during the first year in the Federal District and in some localities in the São Francisco Valley.

In other States where it was not possible to spray rural areas more than once per year this treatment is always scheduled for two months before the annual recrudes-

cence of the disease, or during the beginning of that period. Doubtless two sprayings would offer better results, but our country is so enormous that if we were compelled to apply two systematic house sprayings with DDT per year to all the localities under treatment, many distant regions would have to wait for some time. Although we have not been able to eliminate malaria completely in all of the areas where DDT has been applied once per year, gross transmission has been stopped in all of them. At present, only some 12 per cent of the houses sprayed with DDT by the National Malaria Service receive two treatments per year.

DDT is most commonly used as a water emulsion prepared from a 30 per cent emulsion concentrate. In the beginning of our program xylene was employed as the solvent and Triton X-100 as the emulsifying agent. These chemicals had to be imported. Recently a mixture of xylene-toluene-benzene has been substituted for xylene.

Fig. 5

Fig. 6

Fig. 5. Municipios worked by the National Malaria Service of Brazil in 1945. Anti-larval measures predominated, including drainage and the application of larvicides.

Fig. 6. Municipios worked by the National Malaria Service of Brazil in 1949. With the exception of four localities in Santa Catarina, all other areas were treated with DDT. The areas marked 1 were not under the control of the National Malaria Service in 1949. Malaria is absent from the areas marked 2.

It is obtained from the Companhia Siderúrgica Nacional at Volta Redonda. A monoglycerate made from castor oil and glycerine is used as the emulsifying agent. This preparation, which has been given the designation B-13, is manufactured at the Institute of Malariology of the National Malaria Service (Kemp and Barragat, 1950). The cost of this emulsifying agent is Cr$8.25* per kilo, or approximately one-third the price of the imported Triton (Romeiro *et al.*, 1950). The aqueous emulsion obtained with B-13 is stable, and as satisfactory as the emulsion previously prepared with Triton.

The central mixing plant in Rio de Janeiro has a capacity of 80,000 liters of 30 per cent emulsion concentrate per day. Samples of the emulsion concentrate are tested before being sent to the field. This product is shipped all over Brazil in 200-

* One Cr. (cruzeiro) equals 5 cents U. S., approx.

liter drums. Suspensions of wettable DDT powder are also commonly used, particularly in the more primitive types of rural houses with walls made of straw or clay. During 1949 about 80 per cent of the DDT used was in the form of an emulsion, and approximately 20 per cent as a suspension of the wettable powder.

The quantity of DDT applied varies from 1.5 to 2.0 grams per square meter. At first both walls and ceilings were sprayed, but recently the ceilings have not been treated, except in the region of *Kerteszia*-transmitted malaria. In areas where malaria is carried by *A. darlingi*, *A. aquasalis* or *A. albitarsis* the present tendency is to treat walls and ceilings up to a height that can be conveniently reached with the usual spray gun. Deane and Damasceno (1948), Rachou *et al.*, (1949), and Corrêa *et al.*, (1948) showed that most of the mosquitoes of these three species are found inside houses resting on the walls below the three meter level. Rachou and Lima (1950) observed that in houses where the walls were adorned with a dark painted band, even if this was only a narrow strip, anophelines of the subgenus *Kerteszia* would rest by preference on this band. Whenever two painted strips existed, the upper one would be selected by those anophelines.

In treated houses every room is sprayed, as well as verandas, privies, and all outhouses. The type of sprayers most commonly used are the Lofstrand, the Smith and the Aeroil. The nozzle preferred for DDT emulsions is the No. 8002 supplied by the Spraying Systems Company, Chicago, Illinois, which gives a fan-shaped spray. For suspensions of wettable powders special sprayers with internal agitators are used. Spraying is done by one operator and one helper, who are assigned to spray an area containing a given number of houses within a certain limit of time. These men travel on foot, on horseback, or any other available transportation, and carry a sufficient amount of concentrated emulsion or wettable powder for several days of work. For every five or six of these teams there is a supervising inspector. This system has proved most satisfactory in regions where transportation is difficult. In areas treated only once a year the work is done by several squads, each made up of four to six operators and two or more helpers. Each squad is headed by an inspector. The squads have their own transportation, and work together so as to cover the area in a short time.

In order to treat adequately such a large number of houses scattered all over Brazil, the National Malaria Service has used all possible means of transportation, from oxcarts to airplanes. The Service has some 500 vehicles, including trucks, jeeps, cars, 12 small airplanes, and 14 motor launches. At the present time the staff of the National Malaria Service numbers 8,000 persons. These include 67 physicians, 6 engineers and 55 entomological technicians.

Experiments with benzene hexachloride have been made in a small locality in the State of Rio de Janeiro where 100 milligrams of the gamma isomer were applied per square meter. The residual lethal effect against anophelines lasted for 45 to 60 days.

In 1947 both the DDT house spraying program and the distribution of antimalarial drugs to the rural population was greatly amplified. Chloroquine diphosphate (Aralen) was used, given in a single dose of one gram to adults, and in decreasing doses to children according to their age. With this measure we have placed at the disposal of the population in the malarious areas a specific means of protection

until DDT house sprayings can be carried out. At present there are 19,441 drug distributing units in the malarious areas of this country. It has been observed that wherever houses have been treated with DDT the use of antimalarial drugs has decreased considerably.

The budgets of the National Malaria Service for the years from 1942 to 1950 inclusive are given in Table 5. The successive increases in these appropriations are noteworthy, particularly those after 1946. In addition to the regular budget of the Service received from the Federal Government during the period from 1947 to 1950, other financial contributions were made available by some of the States; these amounted to a total of Cr$16,783,333. The per capita expenditure for the nation rose from Cr$0.34 in 1942 to Cr$4.28 in 1949. The cost per house sprayed was Cr-$70.58 in 1949.

TABLE 5

Appropriations received by the National Malaria Service

(In Cruzeiros*)

YEAR	REGULAR FEDERAL BUDGET APPROPRIATIONS	ADDITIONAL CONTRIBUTIONS RECEIVED FROM THE VARIOUS STATES	TOTAL
1942	15,033,000	—	15,033,000
1943	24,462,840	—	24,462,840
1944	35,007,298	—	35,007,298
1945	48,430,230	—	48,430,230
1946	84,900,310	—	84,900,310
1947	109,630,970	2,500,000	112,130,970
1948	133,797,680	4,000,000	137,797,680
1949	207,329,470	5,700,000	213,029,470
1950	187,153,910	4,583,333	191,737,243

* One Cruzeiro equals 5 cents U. S. (approx.)

RESULTS OBTAINED

Results of the nation-wide malaria control program based on house sprayings with DDT have been excellent. This insecticide has proved highly effective against *A. darlingi*, *A. aquasalis*, *A. albitarsis*, *A. cruzii*, and *A. bellator*, our principal vectors.

The efficiency of DDT applications is assayed by chemical and biological tests. The latter are carried out by the method described by Bustamante and Mata Pires (1950). Chemical tests of the colorimetric type and an improved turbidity test developed by Kemp and Aguiar (1950) permit the calculation of the amount of DDT deposited on sprayed surfaces.

A summary of the general results of the antimalarial campaign has been presented by Pinotti (1950). The efficacy of the program was estimated by comparing the numbers of anopheline mosquitoes captured in houses, the blood parasite and spleen indices, and the malaria morbidity and mortality rates before and after the application of DDT.

The initial effect obtained by house sprayings with DDT was the spectacular disappearance of all anopheline mosquitoes from the interior of human dwellings.

This development was observed with all five of the Brazilian vector species after the first treatment with DDT.

Table 6 shows the effect of DDT on the number of *A. darlingi* captured inside houses in six localities situated in the São Francisco River valley.

Similar results were obtained with *A. albitarsis*, with *A. aquasalis*, and with two species of *Kerteszia*. The striking fall in the numbers of Anopheles mosquitoes captured inside houses at Magé in the State of Rió de Janeiro, and at Blumenau in the State of Santa Catarina, following the widespread use of DDT is indicated in figure 7. The decrease in house captures at Blumenau may have been partially due to cutting down the forest around the town in 1947 and 1948. The first general application of

TABLE 6

Effect of DDT on the prevalence of A. darlingi *inside houses in six localities situated in the São Francisco River Valley*

(First application of DDT made during 1947)

LOCALITY	MONTH AND YEAR	NO. OF HOUSES INSPECTED	NO. OF *A. darlingi* CAPTURED
Bom Jesus da Lapa (Bahia)	March, 1947	258	372
	April, 1948	272	5
	May, 1949	300	0
Ibotirama (Bahia)	March, 1947	118	112
	May, 1948	146	0
	April, 1949	147	0
Morpará (Bahia)	Feb., 1947	94	142
	March, 1948	102	8
	April, 1949	97	0
Januária (Minas Gerais)	April, 1947	46	335
	May, 1948	400	0
	May, 1949	400	0
Guacúi (Minas Gerais)	April, 1947	5	76
	May, 1948	41	0
	April, 1950	41	0
São Romão (Minas Gerais)	April, 1947	30	243
	May, 1948	232	0
	May, 1950	232	0

DDT at Magé was carried out in December 1947, and at Blumenau in January 1949. *A. aquasalis* is the most prevalent species found in houses at Magé, and *Kerteszia* species at Blumenau.

The diminishing number of *Kerteszias* found in the houses of Brusque (Santa Catarina) after deforestation is shown in Table 7. This was the only antimalarial measure used against *A. cruzii* in this locality. Cutting down the forest around Brusque was first started in 1946, and as this procedure advanced the number of *A. cruzii* captured inside houses continued to fall. The few specimens of *Kerteszia* mosquitoes still found during 1949 were captured in houses on the outskirts of the city.

In all important localities the Service had figures available showing malaria

morbidity, which made it possible to evaluate the effect of DDT on the transmission of the disease. Attempts to discover malaria patients were carried out with the same zeal both before and after the application of DDT. Sanitary inspectors made daily or weekly visits to the houses in the urban and suburban zones of the localities worked, investigating the existence of active or recent malaria cases (fever). Blood samples were collected from all suspected cases. If the paroxysm occurred during

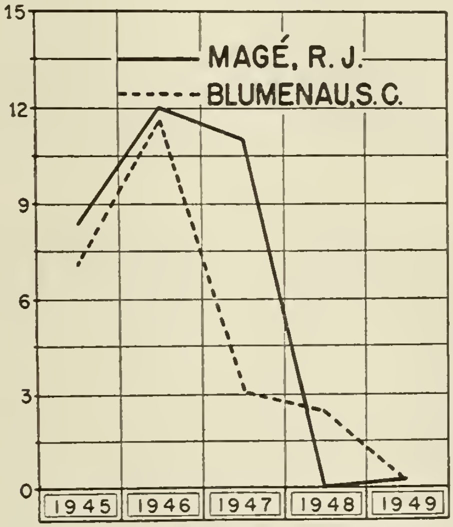

FIG. 7. Effect of DDT on the numbers of *A. aquasalis* captured inside houses at Magé (Rio de Janeiro), and on the numbers of *Kerteszia* anophelines taken at Blumenau (Santa Catarina).

TABLE 7

Effect of cutting down the forest on the prevalence of adult kerteszia anophelines inside houses at Brusque, Santa Catarina

YEAR	NO. OF HOUSES INSPECTED	NO. OF ANOPHELINES CAPTURED (*Kerteszia* SPP.)	NO. OF ANOPHELINES CAPTURED PER 100 HOUSES INSPECTED
1945	6,887	1,261	18.31
1946	11,170	547	4.90
1947	7,691	62	0.81
1948	7,465	56	0.75
1949	7,485	51	0.70

the interval between two visits, the patient called in person or notified the National Malaria Service office in his locality. In the latter instance he was visited without delay. Under this arrangement it is possible to compare the figures of malaria cases during the different years in different parts of the country.

Cities and towns from which malaria morbidity data, recorded by the Service, can be used for the evaluation of the effect of DDT on the incidence of the disease, are not very numerous. However, information is available concerning the prevalence

of malaria before and after the use of DDT in many localities in the country; data from eleven of these localities are summarized in Table 8. In five of them, Duque de Caxias, Magé, Saquarema, Macaé, and the Federal District, the disease is transmitted principally by *A. aquasalis*; in four others, Japerí, Caramujos, Guapimirim, and Piraí, the transmission is by *A. darlingi*. In Salvador and Santo Amaro de Ipitanga *A. albitarsis* is the vector. In most of these localities all three vectors have been found, although one species usually predominates in each area. Typical reductions in malaria morbidity are shown graphically in figure 8.

Malaria morbidity rates per 100,000 inhabitants in the Federal District are shown in figure 9. From 1943 to 1946 there was a steady decrease in malaria incidence, an increase in 1947, with a rapid fall in 1948 and 1949. The drop in malaria prevalence during the period from 1943 to 1946 inclusive was probably due to drainage work

TABLE 8

Effect of DDT on Malaria morbidity in localities treated twice per year where the vectors are A. aquasalis, A. darlingi and A. albitarsis

(Number of cases confirmed by microscopic examination of the blood)

LOCALITY	1945	1946	1947	1948	1949
1. Duque de Caxias, Rio de Janeiro	2,757	2,292	3,663	487	182
2. Japerí, Rio de Janeiro	172	216	379	6	1
3. Caramujos, Rio de Janeiro	153	200	124	0	0
4. Guapimirim, Rio de Janeiro	504	109	132	35	2
5. Magé, Rio de Janeiro	1,804	1,116	1,439	123	21
6. Saquarema, Rio de Janeiro	166	105	143	61	19
7. Macaé, Rio de Janeiro	2,337	1,085	888	269	61
8. Piraí, Rio de Janeiro	180	492	218	64	8
9. Federal District	3,893	3,229	4,970	1,723	414
10. Salvador, Bahia	1,976	2,059	2,024	1,411	408
11. Sto. Amaro de Ipitanga, Bahia	840	585	218	365	76

Localities 1 to 9—First treatment with DDT made in December, 1947.
Locality 10—Partial treatments made in 1947 and 1948, first general treatment in 1949.
Locality 11—First treatment with DDT in October, 1946.

and application of larvicides. The increase observed in 1947 may perhaps represent a five-year cyclic recrudescence of the disease.

Spleen and blood parasite surveys were carried out in selected areas known to have high indices, among children from 2 to 14 years of age, with special emphasis on the 5 to 14 year group. The examinations were usually made in schools. Hackett's classification of splenomegalies was adopted, the child being examined while lying down with its legs flexed. Blood samples were collected from all children at the time of the spleen examination in order to determine the parasite index. Blood films were also taken from children under one year of age to ascertain the transmission index. On small farms and in rural settlements, which are at times the only malarious localities in a county, parasite indices were secured on individuals of all ages, because the number of children was so small. Table 9 summarizes parasite indices at fourteen localities in four States before and after treatments with DDT.

The reductions observed in the parasite indices of some of the localities mentioned in Table 9 are also shown in figure 10.

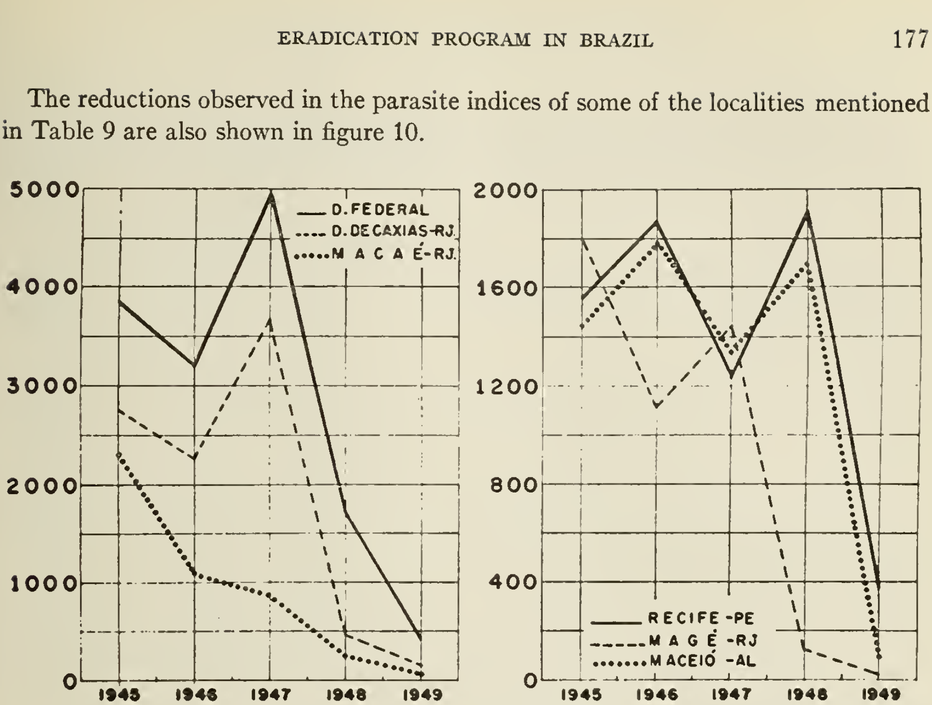

FIG. 8. Effect of DDT on malaria in areas where this disease is carried by *A. aquasalis*. The first application of DDT in the Federal District, Duque de Caxias, Macaé and Magé was carried out in December, 1947, and in Recife and Maceió during March-April, 1949. All cases of malaria were diagnosed by microscopic examination of blood films.

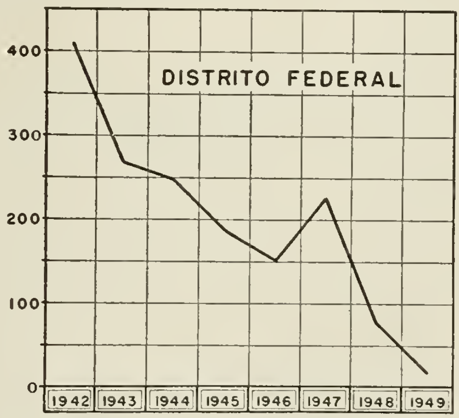

FIG. 9. Malaria morbidity rates per 100,000 inhabitants from 1942 to 1949 inclusive for the Federal District. Regular applications with DDT started in December, 1947.

The parasite index among newborn children was as a rule taken during what would have been the peak period of malaria transmission. This index has sometimes been called the "transmission index." Usually the rate approached zero after treatment with DDT, which indicated that transmission had been stopped. In 1948 eight positive slides from newborn infants were found among 13,027 blood films secured

TABLE 9

Effect of DDT on the parasite rates in localities where malaria is carried by A. darlingi *and* A. aquasalis. *Two DDT Sprayings were given per year, the first in 1947*

LOCALITY	STATE	YEAR	NUMBER OF BLOOD FILMS EXAMINED	NUMBER POSITIVE	PER CENT POSITIVE
Bem Bom, Bom Jesus da Lapa, Malhada, Ibotirama, Jupaguá, Sobrado, Junco*	Bahia	1947	782	71	9.08
		1948	723	18	2.49
		1949	786	1	0.12
		1950	893	3	0.34
Januária and Pedras de Maria da Cruz*	Minas Gerais	1947	740	34	4.59
		1948	630	1	0.16
		1949	724	2	0.28
		1950	840	0	0
Parapitinga, Ilha das Flores and Saúde†	Sergipe	1947	647	70	10.82
		1950	587	1	0.17
Guia de Pacobaíba and Corôa Grande‡	Rio de Janeiro	1947	202	28	13.86
		1948	222	0	0
		1949	123	0	0
		1950	209	0	0

* Area in which the vector is *A. darlingi.*

† Area in which the vectors are *A. darlingi* and *A. aquasalis.*

‡ Area in which the vector is *A. aquasalis.*

For all localities shown in Table 9 the parasite index has been taken for each of the four years, except in Junco (Bahia) and Pedras de Maria da Cruz (Minas Gerais) where it was taken only in 1947 and 1950, and in Corôa Grande (Rio de Janeiro) where the index was not taken during 1949.

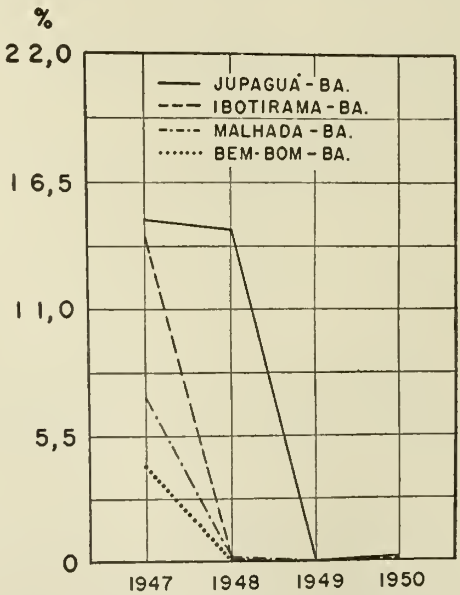

FIG. 10. The effect of DDT on the parasite index in an area where malaria is carried by *A. darlingi* and *A. aquasalis.* For each locality the first parasite index was taken prior to the first DDT spraying. DDT was applied twice per year.

in four States and the Federal District. The next year (1949) 67,857 infants were examined in the States of Espírito Santo, Goiás, Paraná, Pernambuco, Rio de Janeiro, Rio Grande do Sul, and the Federal District. Only fourteen positives were encountered among them, which showed that malaria transmission in those areas had virtually ceased.

The decrease in the spleen index in areas treated with DDT was slower than the fall in blood parasite rates. In endemic zones where the disease is carried by *A. darlingi* this decline seems to have been less marked than in regions where *A. aquasalis* is the vector.

Giglioli (1948) and Gabaldon (1949) have reported that *A. darlingi* seems to be disappearing from British Guiana and Venezuela, respectively, as a result of house sprayings with DDT. According to our observations, *darlingi* seems to be disappearing from certain areas, while in others, that have been treated with DDT twice yearly since 1947, the density of this species is still very high. In the São Francisco valley, however, night captures with animal bait made outside houses suggest that the density of *A. darlingi* may be diminishing in certain localities, though not in the rapid manner which has been observed in British Guiana and Venezuela. At Engenheiro Dolabela in the State of Minas Gerais, on the other hand, the numbers of *A. darlingi* being captured are still very high, in spite of the fact that all the houses in that locality have been treated with DDT since 1946.

Our extended DDT program has not yet been concluded, because some 20 to 25 per cent of the houses in the malarious areas of Brazil still remain to be sprayed. However, the large majority of our people who are exposed to this disease are already being protected by the use of DDT. Along with the progressive increase of the area worked, we are also trying to improve the efficiency of our campaign.

SUMMARY

Brazil has an area of 8,516,037 square kilometres and its population on 31 December 1948 was estimated to be 48,900,000. Only two official agencies are at present responsible for malaria control in this Republic, the National Malaria Service, which is a federal organization under the National Department of Health of the Ministry of Education and Health, and the Prophylactic Malaria Service of the Health Department of the State of São Paulo. This paper deals with the activities of the National Malaria Service, especially its nation-wide program of DDT house spraying which has been underway since 1947.

Malaria is present in all of the twenty States, the Federal District, and the four Federal Territories. Endemic or epidemic malaria is found in areas equivalent to about 85 per cent of the total area of Brazil. The exposed population has been estimated to be at least 17 millions. The principal malaria vectors are *A.* (*N.*) *darlingi* *A.* (*N.*) *aquasalis*, *A.* (*N.*) *albitarsis*, *A.* (*K.*) *cruzii*, and *A.* (*K.*) *bellator*.

Until 1946 control measures were directed against the aquatic phases of the anopheline vectors. They included drainage and the application of larvicides, mainly Paris green. Such measures were limited to the principal cities of each state; the free distribution of antimalarial drugs was the only practical means available before 1947 for assisting the rural population.

Initial experiments with DDT were begun in 1945; these were so encouraging that

an expanded DDT house spraying program was undertaken in 1947 with the result that two years later 2,364,279 houses were being treated.

The National Malaria Service now has a staff of 8,000 employees, including 67 physicians and 6 engineers, as well as a rolling stock of approximately 500 vehicles of different types, and 12 airplanes. Federal appropriations for this Service have increased from Cr$15,033,000 in 1942 to Cr$207,329,470 in 1949. In addition to the regular budget, contributions were also received from some of the State Governments. The cost per house during 1949 was Cr$70.58 ($3.50 U. S., approximately).

The results obtained so far are excellent, both in areas where malaria is carried by anophelines of the subgenus *Nyssorhynchus* as well as in other zones where *Kerteszia* species have been incriminated. In the latter region a great reduction in malaria incidence was secured at Florianópolis where manual removal of bromeliads was all that was necessary. Cutting down the forests surrounding Brusque and other towns, which harbored arboreal bromeliads, has likewise proved to be an effective measure. The decreases observed in malaria morbidity and in blood parasite rates have been most encouraging, and they suggest that eradication of the disease from large sections of this country may eventually be achieved.

It is estimated that about 20 per cent of all houses situated in the malarious areas of Brazil have not yet been reached by the DDT house spraying program of the National Malaria Service. The majority of these dwellings are located in isolated regions of the States of Pará, Amazonas, Mato Grosso, Goiás, Maranhão, and Piauí, where means of transportation are few and conditions of work exceedingly difficult. It will be some time, therefore, before they can all be included within our program.

REFERENCES

Bustamante, F. M., and Ferreira, M. O. 1949. Da aplicação intradomiciliar de DDT no combate à malária transmitida por *Kerteszia*. Rev. Bras. de Malariol., **1:** 205–210.

Bustamante, F. M., Lacerda, N., Paracampos, H., and Santos, O. O. 1949. A malária na bacia do Médio São Francisco. Rev. Bras. de Malariol., **1:** 166.

Bustamante, F. M., and Guedes, A. S. 1950. Armadilha "dawn trap" de Shannon. De seu emprêgo para a captura do *Anopheles darlingi* em Engenheiro Dolabela, Minas Gerais. Rev. Bras. de Malariol., **2:** 49–56.

Bustamante, F. M., Silva Pinto, O., and Guedes, A. S. 1950. Sôbre a captura do *Anopheles darlingi* e do *Anopheles albitarsis* nas paredes externas de casas dedetizadas, em Engenheiro Dolabela, Minas Gerais. Rev. Bras. de Malariol., (in press).

Bustamante, F. M., Ferreira, M. O., and Rachou, R. G. 1949. Da aplicação extradomiciliar de DDT por helicóptero no combate aos anofelinos do sub-gênero *Kerteszia* em matas primárias com predominância de bromélias epífitas. Rev. Bras. de Malariol., **1:** 67–89.

Bustamante, F. M., and Mata Pires, W. 1950. Sôbre um novo dispositivo prático para avaliação da toxicidade de superfícies tratadas com insecticidas de ação residual. Rev. Bras. de Malariol., **2:** 5–22.

Corrêa, R. R., Lima, F. O., and Côda, D. 1948. Informações relativas ao *Anopheles albitarsis domesticus* um dos transmissores de malária no Brasil. Presented at the 7th Brazilian Congress of Hygiene, Sao Paulo, December.

Corrêa, R. R., Lima, F. O., and Côda, D. 1950. Observations on the flight and longevity in nature of *Anopheles albitarsis domesticus*. J. Nat. Malaria Soc., **9:** 280–284.

Deane, L. M., Causey, O. R., and Deane, M. P. 1946. Studies on Brazilian anophelines from the Northeast and Amazon regions. Am. J. Hyg., Monographic series No. 18, p. 5.

Deane, L. M., and Damasceno, R. G. 1948. Altura de pouso das fêmeas de *Anopheles darlingi* e de *Anopheles aquasalis*, nas paredes internas das casas. Presented at the 7th Brazilian Congress of Hygiene, São Paulo, December.

Ferreira, M. O. 1946. Combate específico ao vetor de malária em zona de transmissão por anofelinos do sub-gênero *Kerteszia*. Presented at the 1st International Congress of Medicine, Rio de Janeiro, September. Published in Resumos de Malariologia e Doenças Tropicais, **1**: 1948.

Ferreira, M. O., and Rachou, R. G. 1949. Considerações sôbre métodos profiláticos relativos aos anofelinos do sub-gênero *Kerteszia*. Rev. Bras. de Malariol., **1**: 103–112.

Ferreira, M. O., Rachou, R. G., and Bustamante, F. M. 1949. Da aplicação extradomiciliar de hexaclorobenzene por meio de helicóptero no combate aos anofelinos do sub-gênero *Kerteszia* em matas primárias com predominância de bromélias epífitas. Rev. Bras. de Malariol., **1**: 90–99.

Gabaldon, A. 1949. The nation-wide campaign against malaria in Venezuela. Tr. Roy. Soc. Trop. Med. & Hyg., **43**: 113–160.

Giglioli, G. 1948. Malaria, filariasis and yellow fever in British Guiana. The Daily Chronicle Ltd., Georgetown.

Kemp, H., and Aguiar, H. A. 1950. Método turbidimetrico para determinação de pequenas quantidades de DDT. Rev. Bras. de Malariol., **2**: 318–325.

Kemp, H., and Barragat, P. 1950. Nota prévia sôbre a elaboração de emulsificantes à base de óleos vegetais. Rev. Bras. de Malariol., **2**: 66–71.

Pinotti, M., Rachou, R. G., and Ferreira, M. O. 1947. Algunos aspectos epidemiológicos de la malaria en el litoral sur del Brasil en la zona de transmisión por anofelinos del sub-gênero *Kerteszia*. Tij. S. Malaria, XI.

Pinotti, M. 1951. The biological basis for the campaign against the malaria vectors of Brazil. Tr. Roy. Soc. Trop. Med. & Hyg., (in press).

Rachou, R. G., Bustamante, F. M., and Ferreira, M. O. 1949. Da aplicação extradomiciliar de DDT por helicóptero como meio de combate aos anofelinos do sub-gênero *Kerteszia* em região com predominância de bromélias terrestres. Rev. Bras. de Malariol., **1**: 264–281.

Rachou, R. G., Ricciardi, I., Luz, E., and Garbelini Junior, J. 1949. Observações, no Estado do Paraná, sôbre o pouso dos anofelinos vetores de malária no interior das casas. Rev. Bras. de Malariol., **1**: 288–298.

Rachou, R. G., and Lima, M. M. 1950. Da aplicação de DDT apenas em faixas pintadas nas paredes internas das casas em zona de transmissão de malária por anofelinos do sub-gênero *Kerteszia*. Primeiras provas experimentais. Rev. Bras. de Malariol., (in press).

Romeiro, L., Kemp, H., and Barragat, P. 1950. Desenvolvimento técnico de emulsificantes à base de óleos vegetais. Segunda communicação. Rev. Bras. de Malariol., (in press).

Soper, F. L., and Wilson, D. B. 1943. *Anopheles gambiae* in Brazil 1930 to 1940. The Rockefeller Foundation, New York City. 262 pp.

SUMÁRIO

O Brasil tem uma área de 8.516.037 Km² e sua população em 31 de dezembro de 1948 foi estimada em 48.900.000 habitantes. Apenas dois serviços oficiais são atualmente responsáveis pelo combate à malária nêste país: o Serviço Nacional de Malária, orgão federal subordinado ao Departamento Nacional de Saúde, do Ministério da Educação e Saúde, e o Serviço de Profilaxia da Malária do Departamento de Saúde do Estado de São Paulo. Êste trabalho trata das atividades do Serviço Nacional de Malária, especialmente de seu programa nacional de aplicações domiciliárias de DDT, em desenvolvimento desde 1947.

A malária está presente em todos os 20 estados, no Distrito Federal e nos quatro Territórios Federais, em uma área equivalente a cêrca de 85% da área total do Brasil. Estima-se em pelo menos 17 milhões a população do país exposta à doença. Os

principais vetores de malária são o *A.* (*N.*) *darlingi*, o *A.*(*N.*) *aquasalis* (= *A. tarsimaculatus*), o *A.* (*N.*) *albitarsis*, o *A.* (*K.*) *cruzii* e o *A.* (*K.*) *bellator*.

Até 1946 as medidas de controle eram dirigidas contra as fases aquáticas dos anofelinos vetores e incluiam drenagem e aplicações de larvicidas, especialmente verde Paris. Tais medidas eram porem limitadas as principais cidades de cada estado, de maneira que a distribuição gratuita de medicamentos antimaláricos era a única medida prática disponivel em benefício das populações rurais. Experiências iniciais com o DDT começaram em 1945 e os resultados foram tão encorajadores que um extenso programa de aplicação domiciliària de DDT foi empreendido em 1947 sendo que dois anos mais tarde (1949) 2.364.279 casas estavam sendo tratadas.

O Serviço Nacional de Malária conta agora com cêrca de 8.000 servidores, incluindo 67 médicos e 6 engenheiros, bem como cêrca de 500 veículos, de diferentes tipos, em funcionamento. As verbas orçamentárias do Serviço subiram de Cr$ 15.033.000,00 em 1942 a Cr$ 207.329.470,00 em 1949. Além das verbas regulares, foram também recebidas contribuições dos Governos Estaduais. O custo por casa em 1949 foi de Cr$ 70,58.

Os resultados já obtidos são excelentes, tanto nas áreas com malária transmitida por anofelinos do sub-gênero *Nyssorhynchus* como nas áreas em que as *Kerteszias* são os vetores. Nesta ùltima região uma grande redução na incidência de malária foi conseguida em Florianópolis, onde o arrancamento manual de bromélias foi a única medida empregada. O desmatamento da periferia de Brusque e outras cidades provou igualmente ser uma medida eficaz. As reduções observadas na morbidade por malária e nos índices parasitários foram as mais encorajadoras e sugerem que a erradicação da doença de grandes áreas sistemàticamente tratadas será conseguida brevemente.

Estima-se que uns 20% de todas as casas situadas nas áreas malarígenas do Brasil ainda não foram atingidos pelo programa de dedetização domiciliària do Serviço Nacional de Malária. A maioria dessas casas está localizada nas extensas regiões dos Estados do Pará, Amazonas, Mato Grosso, Goiás, Maranhão e Piauí, onde os meios de transporte e as condições de trabalho são dificílimos. Por êsse motivo, algum tempo será ainda necessário para que todas elas sejam incluidas em nosso programa.

NATION-WIDE MALARIA ERADICATION PROJECTS IN THE AMERICAS

DR. RUSSELL: This has been a long session but I have no doubt about the ability of the last speaker to hold your attention. He has been a friend and colleague for the past 27 years. He is too well known to you to require an introduction. He has been a member of the staff of the International Health Division of The Rockefeller Foundation since 1920, representing the Division in Paraguay, Brazil, Italy, Africa, and the Middle East. His successful campaigns against *Aedes aegypti* and *Anopheles gambiae* are world famous and will long serve as examples of bold planning and skillful administration in the field of public health. During World War II he served on the U.S.A. Typhus Commission and on the Rockefeller Foundation Typhus Team in North Africa and Italy, taking a large part in the elimination of the typhus hazard in this area in 1943–1944. In 1947 he was elected Director of the Pan American Sanitary Bureau, a position to which he was re-elected a few weeks ago. In this office he serves also as the Regional Director for the Americas of the World Health Organization.

He has published many articles of outstanding scientific interest, is a member of numerous professional societies, and has been decorated by the Governments of Cuba, Brazil, Egypt, and the United States of America. He was given the Lasker Award by the American Public Health Association in 1946 and the Theobald Smith medal by the American Academy of Tropical Medicine in 1949. No one is better qualified to discuss the general principles of eradication than Dr. Fred L. Soper.—Dr. Soper.

V. GENERAL PRINCIPLES OF THE ERADICATION PROGRAMS IN THE WESTERN HEMISPHERE

FRED L. SOPER*

This 1950 Symposium of the National Malaria Society on "Nationwide Malaria Eradication Projects in the Americas", is a highly significant landmark in the history of tropical medicine. For the first time since 1901, when Gorgas working in Havana demonstrated conclusively that yellow fever and malaria could be controlled by anti-mosquito measures, the malariologist can legitimately join the yellow fever worker in talking of disease eradication. The advantage is now with the malariologist, who can dry up the sources of human infection, and needs not fear reinfection from animal reservoirs.

The eradication of malaria from rural areas of the tropics may be expected to have more profound effects on these regions than did the elimination of yellow fever from cities and ports several decades ago.

The four papers presented here today describe truly nation-wide eradication projects based on a single method, namely, the spraying of human habitations with residual DDT. These projects cover well over half the malarious regions of the Americas, areas infested by such widely varying mosquito vectors as *Anopheles quadrimaculatus*, *A. darlingi*, *A. albitarsis*, and *A. cruzii*.

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The concept of eradication* implies that the roots of infection are so destroyed that the disease will not reappear, in the absence of reintroduction, even though control measures be discontinued. The worker who is satisfied with disease reduction may well lessen his efforts when the point is reached at which the cost of eliminating the few remaining infections may be much greater than the cost of preventing other important diseases. The worker looking for eradication must press on to the finish, accepting the fact that the greatest cost per case prevented is incurred just before the final success of the project.

Likewise the worker who leaves the seeds of infection in his own district need take no interest in the reduction of the disease in other areas, nor fear its reintroduction from dirty areas. Eradication on the other hand is, and must be an expanding program, since it is most successful when the clean area is largest. The eradicationist must be an internationalist ready to collaborate with other countries in the simultaneous elimination of common dangers and common enemies.

Disease eradication has been the goal of health workers for many years. We have learned today that Frederick Hoffmann proposed the eradication of malaria in the United States in 1915, just about the time Gorgas was embarking on a program for the eradication of yellow fever from the Americas under the auspices of the Rockefeller Foundation, which was also developing campaigns in many countries for the eradication of hookworm disease. However, at that time available methods proved inadequate for the eradication of malaria in the United States. Likewise, epidemiological factors, then unknown, made elimination of yellow fever impossible, and although the incidence of hookworm disease was reduced greatly, nowhere was the worm eradicated.

Under these circumstances, it is not surprising that the Rockefeller Foundation was unwilling to have the term "eradication" used in the anti-*Anopheles gambiae* project in Brazil in 1938, even though it had been shown in the meantime that the *Aedes aegypti* mosquito could be eradicated from the principal cities and even from entire states of Brazil. Only after the elimination of *A. gambiae* from Brazil did the word "eradicate" become respectable once more and acceptable in good public health circles. Even then the term used was "species eradication", since the word "eradication" itself had been so misused. The dramatic results of the eradication of *A. gambiae* in Brazil made it possible to emphasize the importance of the work which was being done in the eradication of *Aedes aegypti*, and in 1940 the Serviço de Febre Amarela of Brazil was reorganized with the declared purpose of eradicating *Aedes aegypti*

* It is interesting to note that the word "eradicate" was applied to disease before the work of Pasteur, and long before Finlay, Manson, Ross, Reed and Gorgas. An American Dictionary of the English Language, Noah Webster (Geo. and Chas. Merriam 1861) defines "eradicate" thus:

"(1) To pull up the roots, or by the roots. Hence to destroy anything that grows; to extirpate; to destroy the roots, so that the plant will not be reproduced; as, to eradicate weeds.

(2) To destroy thoroughly; to extirpate; as to eradicate errors, or false principles, or vice, or disease."

That this reference to disease was to the eradication of disease from a single person rather than from the community is suggested by the classification, at that time, of certain drugs as eradicative. Definition: "Eradicative. N. A medicine that effects a radical cure." And in 1861 very few specific drugs were known, of which quinine was one of the most important.

from the whole of the national territory. This project has made steady progress during the past decade and is now on the eve of completion. Brazil has learned, as all who work with eradication must, that eradication, to be successful, must become an ever-expanding program. In order to protect herself, Brazil proposed to the Directing Council of the Pan American Sanitary Organization in 1947 that a coordinated program for the eradication of *Aedes aegypti* from the Western Hemisphere should be undertaken under the auspices of the Pan American Sanitary Bureau. This proposal was approved, and now almost all of the political units of the Americas are actively participating in this project.

In the meantime, *Anopheles sergenti* has been eradicated from the Oasis of Kharga and Dakhel in Egypt, and favorable progress has been reported in campaigns for the eradication of the vectors of malaria in Sardinia and Cyprus. And so the word "eradicate" has come to have once more its original meaning: "to destroy the roots, so that the plant will not be reproduced". In evaluating species eradication, the final test for local eradication is the failure of the species to reappear, in the absence of reintroduction, after all control measures have been discontinued.

The eradication of malaria may be considered as involving first and foremost, the blocking of all transmission by mosquitoes, and secondarily, the spontaneous or therapeutic cure of infective cases in man. When this state has been reached, reappearance of the disease would depend on both the introduction of infected humans and of the mosquito vector.

Theoretically, malaria can be eradicated in a closed population, that is, in an area receiving no immigrants, by preventing man-mosquito-man transmission until such time as all infected persons become permanently non-infective. Since the man-mosquito-man transmission of malaria is a complex process influenced by each element, man, mosquito, and parasite, the eradicationist can operate on any one, or cumulatively on all three components.

The prevention of transmission may be obtained by:

- (A) Attack on the parasite
  - (1) In man, by therapy of the acute attack or by drug suppression.
  - (2) In the mosquito, by agents of interception, effective only against adults which come to attack man.
- (B) Attack on the insect vector
  - (1) Control of immature stages
    - (a) Making conditions unfavorable for breeding.
    - (b) Anti-larval measures.
  - (2) Anti-adult procedures
    - (a) Prevention of contact, screening, etc.
    - (b) Spraying, direct and/or residual.

During the first three decades after the role of the mosquito in the transmission of malaria became known, little attempt was made to attack specifically the infected or potentially infected adult mosquito. Ironically enough this has come to be recognized as the weakest link in the chain of infection.

In the eradication programs in the United States, Venezuela, British Guiana, and Brazil, the essential factor is the attack on the parasite *in the mosquito* rather than

in man, which is accomplished by striking at the adult mosquito rather than the larva. The intensity of the attack varies according to the domiciliary habits of the vector species.

Although Le Prince working in Panama, had used hand captures of Anopheles mosquitoes in sleeping quarters as a malaria control measure, and Chagas and James had called attention to the importance of the house as the site of transmission, no one used or advocated attack on the infected mosquito until Park-Ross introduced weekly pyrethrum spraying of native quarters for the control of *Anopheles gambiae*-transmitted malaria in Natal, South Africa, almost twenty years ago. Russell confirmed the value of this method for *A. culicifacies*-infested regions in India, even though this species is not highly domestic. Knowledge of these and other similar results was essential and basic to the early trial of DDT as a residual spray for preventing transmission of malaria in various parts of the world. Russell, Andrews, and Kumm, all of whom are taking part in this symposium, had some relation to the field trials in Italy at Castel Volturno in 1944 and in the Tiber Delta in 1945. The test in the Tiber Delta was especially important since malaria in this area had been thoroughly studied and controlled by ditching and Paris-greening by Hackett and Missiroli for many years previously. Following the 1945 demonstration of the value of DDT residual spray, Missiroli publicly (January 1946) announced that drainage and filling was no longer important for the control of malaria in Italy, and that with adequate supplies of DDT, malaria in Italy would disappear as a public health problem within five years. This prophecy has been fulfilled.

Since weekly spraying with pyrethrum had given such good results under varied conditions and with vectors which were not highly domestic, it was logical to believe that residual DDT would prevent transmission of malaria by most of the Anopheline vectors. Thus by 1946 it was recognized that the most urgent task facing the malariologists of the world was to determine if and where areas existed in which residual DDT would not prevent transmission. From today's reports and others at hand it is apparent that the great bulk of the malaria of the Americas is easily suppressed through residual domiciliary spraying. These results are apparently almost equally good against highly domestic species such as *A. darlingi*, in which local species eradication has been achieved by residual spraying, and against species such as *A. albimanus*, of which only a fraction of the adults in an area enter houses. The effect of residual DDT then is essentially on the potentially or actually infected adult mosquito, when it visits human habitations.

The reports submitted today merit detailed study and careful consideration by all who are concerned with malaria as a problem in the Americas. For the first time there exists a single efficient and economical method of attack on malaria which can be standardized and applied with confidence to almost all malarious areas of the Americas.

In the United States, beginning in the middle 1930's, long before the advent of DDT, there has been a steady decrease in malaria throughout the endemic regions in uncontrolled as well as in controlled areas. Some workers have attributed this decline to the widespread employment of insecticidal sprays for household use. The United States program for the eradication of malaria, which does not contemplate

the complete elimination of *Anopheles quadrimaculatus*, is the logical one to pursue, considering the difficulty of destroying this species, and the enormous area it inhabits. However, after eradication of malaria is achieved, its continued absence will depend on the number and distribution of infective immigrants, and the extent to which official agencies or individual families continue to use household insecticides.

The situation in the United States is favorable to the eradication of the disease because:

(1) Anopheline mosquitoes are generally more susceptible to insecticides than are flies and other noxious insects.

(2) The people, once accustomed to homes without insects, will take community and individual measures against these insects.

(3) The development of malaria eradication projects in other countries lessens the danger of importation of new cases.

(4) The development and use of improved drugs of low cost for suppression and radical cure of malaria will cause a diminution of the disease.

But even so, the United States and every other country, as it becomes free of malaria, can be shown to have a direct stake in the malaria eradication projects of other nations.

This symposium is extremely fortunate in having reports in person from the directors of the malaria studies and control projects in both Venezuela and British Guiana, where careful research has been done for many years (Venezuela since 1936, British Guiana since 1933) before the advent of DDT, and where this agent was introduced early before it became generally available in other parts of the world.

Venezuela lies in a transitional faunal zone in which various vectors of malaria are found, the two most important being *A. albimanus* and *A. darlingi*, which differ widely in domesticity.

Transmission of malaria by each of these vectors had been found subject to control by weekly spraying with pyrethrum before DDT came on the scene. The early results with residual DDT reported from Venezuela were most important, since they indicated that this measure would be applicable over enormous areas in South and Central America and the West Indies in which one or the other of the two Anopheles mentioned above are the principal vectors of malaria.

The malariologists in Venezuela take great care in preparing specifications for the insecticides purchased by them and follow up with routine chemical and other tests on the materials received. The development of satisfactory high percentage DDT-wettable powders is in large part due to this service, which has set new standards for the marketing of insecticides to the benefit of all purchasers. The fact that workers in Venezuela have always known what they were working with has facilitated the determination of standards for field work under Venezuelan conditions.

With the results of the first two years of extensive use of residual DDT at hand, the health authorities of Venezuela realized that a technique for the eradication of malaria was now available, and that with malaria control measures now brought entirely within the domicile, it would be advantageous to have a single service responsible for the control of all diseases transmitted to man by arthropods. At the end of 1947, the malaria service became responsible for the eradication of *Aedes aegypti*

from Venezuela. The importance of having a single service responsible for the control of all diseases depending on various types of infestation of human habitations was emphasized in 1949, when it became evident that the prolonged use of residual DDT was bringing about an increase of *Rhodnius prolixus*, an important vector of Chagas' disease. The malariologist cannot be satisfied with the eradication of malaria, but must be ready to work toward freeing human habitations of arthropods of all kinds. Once malaria disappears, interest in household pests, other than mosquitoes, may well be the key to continued work needed to keep malaria out.

One cannot doubt that malaria eradication is imminent in Venezuela, when one learns that persons engaged in smuggling are identified as such by blood examination, as they become infected with malaria before entering Venezuela. So little malaria now occurs that the Malaria Service is willing to consider all cases as new infections unless proved otherwise. The observation that very few malaria relapses occur after the first two years of spraying is very important for an understanding of the epidemiology of the disease, and is in accord with the blood survey figures in the *gambiae*-infested area of Brazil, where the parasite index dropped from 65.5 per cent to 0.9 per cent in two years (1939–1941).

The radical changes reported in the vital statistics of Venezuela and British Guiana are most significant, and are in keeping with those occurring in malarious regions all over the world following the introduction of residual insecticides. The increasing populations of previously malarious areas are a challenge which must be met by better health services, better schools, better transportation, and especially by improved agricultural methods.

British Guiana has been an ideal setting for the demonstration of the dramatic results which follow when malaria transmission suddenly ceases in a formerly highly endemic area. Because the two principal crops in British Guiana (rice and sugar cane) are irrigated, drainage as an anti-larval measure is impossible, and the use of larvicides is impracticable, but conditions are ideal for residual spraying, since the bulk of the population is concentrated in a small area and comparatively few of the houses are of mud and wattle construction. *Anopheles darlingi* is the only important vector of malaria in British Guiana, and is so highly domestic there that species eradication has been accomplished, no *darlingi* having been found in the sprayed areas for three years. This experience in British Guiana raises the question whether *darlingi* is equally domestic throughout its entire range, or is highly domestic in British Guiana and semisylvatic in the Amazon Valley and elsewhere in its extensive range in South America. The fixity of habit of a given species is of great practical importance. *Aedes aegypti* is susceptible to eradication in the Americas largely because it has never become adapted to the forests of the New World, although in its native home in Africa, it is widely dispersed in forests. Are these diverse behaviors in America and Africa due to differences in characteristics of the forests, or to discrete differences in the physiology of the mosquito? Tests should be made of the adaptability of the *aegypti* of African towns to life in the African forest, and of the *aegypti* of the forests to life in the towns, to determine whether urban eradication of *aegypti* is feasible in Africa as it is in the New World.

In discussing the attempted eradication of *A. labranchiae* from Sardinia, it has

been suggested that it is much more difficult to eradicate an indigenous species than an imported one. This raises the question of where a species is indigenous. Is *Anopheles darlingi* indigenous in Venezuela and British Guiana where its local eradication by residual DDT has been observed, or is it a recent importation existing under marginal conditions? The apparent eradication of *A. darlingi* from a stretch of the valley of the Rio Doce in Brazil during several years following the intensive use of Paris green as a larvicide may be significant or not. Are the few remaining *labranchiae* in Sardinia direct descendants of the *labranchiae* of thousands of years ago before adaptation to life with man occurred and, therefore, incapable of building up the heavy infestation responsible for the previous highly malarious state of the island? Only time and further observation will clarify these points.

In British Guiana, we have an island of eradication established on the mainland of South America, a situation analogous to that which existed in Brazil when *Aedes aegypti* began to disappear from city after city along the coast. The experience with the reinvasion of British Guiana by *Anopheles darlingi* in 1941 after a prolonged drought is most encouraging, since this reinvasion was gradual and might have been easily controlled by residual spraying of an adequate barrier area, just as the spread of *A. gambiae* in Northeast Brazil was halted in 1939 by a barrier zone of larviciding with Paris green. Although British Guiana plans permanent spraying of only a fourth to a third of the houses to form a barrier zone and to spray these only every 18 months, the mathematics of the situation make it imperative to get as large a zone as possible cleared, since only thus can the cost of the peripheral barrier be reduced to a minimum. It is obviously to the interest of British Guiana to have *A. darlingi* eradicated from Dutch Guiana, Venezuela, and Northern Brazil, so that no barrier zone would be needed. This problem in coordination of national health programs can best be solved by official international organizations such as the Pan American Sanitary Bureau or the World Health Organization.

The remarkable results obtained in British Guiana with rather long intervals between applications of DDT emphasize the disadvantages of mud and wattle type habitations in the tropics. DDT residual spray is less effective in this sort of construction, which is not common in British Guiana. Future studies on suitable housing for the tropics should include investigation of the liability of various kinds of house construction to insect infestation, and adaptation to insecticidal action.

An important additional result of the use of residual DDT in British Guiana has been the final eradication of *Aedes aegypti* from the coastal plain, where anti-larval measures had been applied since 1939. The yellow fever mosquito is even more vulnerable to DDT residual spray than are the Anopheles mosquitoes.

Brazil, the largest of the American Republics, has a malaria problem involving all its states and territories. The National Malaria Service has been given greatly increased funds in recent years, and has undertaken the gigantic task of eradicating malaria from this vast tropical and subtropical empire. The National Malaria Service works largely through agreements with and contributions from local governments, and has come to have the responsibility for malaria control in all of Brazil, except the single powerful state of São Paulo.

Although the control of malaria is highly centralized, evidence of decentralization

is already apparent. Malaria control zones have been established in certain areas containing 1,000 to 1,600 houses, and are put in charge of a well trained local resident who is responsible for the routine spraying of all houses in his zone at regular intervals. The local worker furnishes his own transportation and receives only his salary, and the equipment and insecticide required. His work is checked occasionally by the Malaria Service.

Brazil has many types of malaria problems, all of which are apparently soluble with residual DDT. But Brazil also has other important arthropod-borne diseases including yellow fever, plague, Chagas' disease and dysentery. Eventually the orientation and follow-up of the general house disinfestation programs now carried out by several decentralized administrative services should rest in the hands of a single central service.

As each country approaches eradication of any disease or of any disease vector in its own territory, it immediately acquires an active interest in measures for similar eradication projects in those countries with which it has direct or indirect contact, and through which it might be reinfected or reinfested.

It is important then to consider the malaria eradication programs in the United States, Venezuela, Brazil, and British Guiana, in connection with similar projects in other parts of the Americas. Fortunately for this discussion Dr. Carlos Alvarado, Regional Adviser on Malaria to the Pan American Sanitary Bureau, recently completed a survey of anti-malarial activities in the Americas which was summarized in the 4th Report to the XIII Pan American Sanitary Conference on the campaign against malaria in the American Continent (September 1950). This report is most encouraging, as it indicates that other nations of the Americas are either now or should soon be in the same favorable position as the United States, Venezuela, Brazil, and British Guiana.

The eradication of malaria in Argentina involves two quite distinct problems:

(1) Control of *A. pseudopunctipennis*, the sole vector in the northwestern endemic zone, covering parts of seven provinces with an area of 120,000 square kilometers, 225,000 houses and a population of 1,250,000, and

(2) Control of *Anopheles darlingi* and *A. albitarsis*, the vectors in the northeastern epidemic zone bordering on Brazil and Paraguay, with an area of 150,000 square kilometers and 500,000 inhabitants.

From the economic point of view, endemic malaria in Argentina has been much more important than epidemic malaria. For many years control measures have been concentrated largely in the zone infested by *A. pseudopunctipennis*; the data which follow refer to this zone except as stated otherwise.

In 1947, when the decision was taken to depend entirely on residual DDT, public burial with appropriate funeral rites was held for ditching and larvicidal equipment and materials to impress on the employees of the malaria service and on the public that a new era in the control of malaria had come. In less than four years Argentina has practically eliminated the problem of endemic malaria, and the Division of Malaria and Endemic Diseases has become the Department of Health for Northern Argentina.

Although the Argentine law relating to malaria (Law 5195 modified by Law 13266,

Sept. 1948, and Decree 9624) does not use the word "eradication", such is obviously the objective. In the endemic zone of Argentina it is obligatory:

(1) to spray all houses with residual insecticide at regular intervals,
(2) to report all suspected malaria cases within 24 hours,
(3) to submit blood smears for confirmation, and
(4) to dispense antimalarial drugs only on the prescription of a physician.

Argentina is handling malaria as a pestilential disease which should not exist in the endemic zone, and is taking the responsibility of investigating each case which occurs. The restriction on the sale of antimalarial drugs is used to get information on the incidence of the disease and is quite in contrast to the distribution by the government of large amounts of such drugs in previous years (in 1946, 256,823 treatments).

A solution of DDT in kerosene is generally used, because this solvent is available locally. Only the walls of the sleeping quarters are sprayed, resulting in considerable economy of labor and material. From August 1949 to May 1950, 171,000 (76 per cent) of the houses in the endemic zone were sprayed. The remaining houses were so situated in the center of towns and cities that spraying was not needed. Reported cases of malaria dropped from 129,248 in 1945 to 5,324 in 1949. (In the same period reported cases in the United States dropped from 62,763 to 4,241). In 1945, blood examination of 50,866 patients gave 24,161 (47.5 per cent) positives, but in 1949 examination of 9,154 patients gave only 568 (6.2 per cent) positives. Only 232 new cases were found in the endemic zone in 1949. A survey of 14,581 school children in 1945 with 10.9 per cent positive bloods is to be compared with a similar survey of 50,652 children in 1949 with only 0.1 per cent of the slides positive. The percentage reduction among pre-school children under 5 years of age was even more pronounced (in 1945, 7,325 examined, 8.9 per cent positive; in 1949, 9,008 examined, 0.05 per cent positive).

In the epidemic zone, where the incidence of malaria may vary greatly from year to year, only 10 per cent of the population was protected by residual DDT in 1949, and 15 per cent in 1950, as compared with 100 per cent of the population in the endemic zone. The plan for 1951 calls for full protection of the epidemic zone, even though 1949 conditions were excellent, with only 152 cases of malaria reported, and a blood parasite index in school children of only 0.1 per cent.

In discussing the eradication of malaria from the Americas, Uruguay and Chile can be eliminated entirely, since Uruguay has no malaria and Chile reported the complete eradication of its only vector, *A. pseudopunctipennis*, in 1948.

Ecuador (Law of 2 December 1948) declared the "eradication of malaria to be an urgent national problem" and established the national malaria service under the National Institute of Health. This service has concentrated its efforts on the use of residual DDT. The Government of Ecuador increased the malaria budget from 400,000 sucres in 1948 to 6,220,000 sucres in 1950, or over 1,500 per cent. It is estimated that 68 per cent of the houses in the endemic zone have been sprayed once or twice in 1950, and the future program calls for complete coverage of the dangerous area.

Costa Rica, El Salvador, Guatemala, Honduras, British Honduras, and Nicaragua

joined in a simultaneous campaign during 1950–51 against household insects, largely oriented toward the eradication of malaria, under the technical advice of the PASB/WHO, with supplies furnished from a fund of half a million dollars made available by UNICEF.

Panama had a well organized service for residual spraying, covering much of the exposed population of the Republic when jungle yellow fever was discovered there in January 1949. The additional funds made available for anti-*Aedes aegypti* measures were used by the Malaria Service for spraying such towns as were still infested with this mosquito, thereby increasing the coverage against malaria. Although definite figures are not available, malaria has become very uncommon in Panama; unfortunately, following a recent change of Government, the rumor has circulated that a return to drainage and anti-larval measures is planned.

In Paraguay the PASB/WHO and UNICEF have agreed to collaborate with the Government in transforming the *Aedes aegypti* eradication service into a National Malaria Service in 1951.

French Guiana reports having sprayed all the houses in that Colony with the consequent suppression of malaria transmission and the eradication of *Aedes aegypti.*

There is not time and space to discuss the situation in each of the remaining countries in detail. Haiti, Nicaragua, and Costa Rica are the only countries which do not have special services for malaria control, and in Honduras and Colombia the Malaria Service is part of the Service maintained by the Institute of Inter-American Affairs. In Bolivia, Peru, Colombia, and Mexico, DDT as a residual spray has given the same good results as elsewhere in the Americas, and plans are being made for extension of its use in these countries. Cuba has made a beginning with DDT during the past year, and plans have been made for antimalaria programs in the Dominican Republic and Haiti. In 1950 only in Mexico, Jamaica, and Colombia are more people protected from malaria by engineering projects than by residual insecticide, and in many countries the only control measure used is residual house spraying with DDT.

In the 3rd Pan American Report on Malaria to the XII Pan American Sanitary Conference (Caracas 1947) it was foretold that the introduction of DDT would result in a great reduction in other methods of malaria control, while at the same time vast areas of the American tropics which had been untouched by any effective antimalaria measures would begin to receive the benefits of this most practical measure of control. This prediction has been more than borne out by the facts reported here today. It has been amply demonstrated, for the Americas at least, that periodic spraying with DDT will suppress the transmission of malaria within human habitations. Where extra-domiciliary transmission of malaria does occur, it must be due in great part to the infection of mosquitoes from gametocyte carriers which were originally infected in habitations. As house transmission of malaria disappears, outside transmission should disappear rapidly also.

Considering that it is only five years since DDT became available, and that approximately 75 per cent of the habitations in the malarious regions of the Americas are in countries with nation-wide programs for the eradication of malaria, it is not too much to anticipate that the rest of the job can be done during the next five years,

if full advantage is taken of the services of the international organizations responsible for coordination of health activities in the Americas.

RESUMEN

Nuevas posibilidades en el control de malaria descubiertas con el advenimiento de DDT usado en hogares como un insecticida residual se han discutido con relación al problema en Norte y Sur América.

El concepto de "exterminación" implica que la cuna de infección debe ser eliminada de manera que en la ausencia de una nueva introducción, nuevos casos no apareceran. Es probable que la exterminación de malaria puede efectuarse en algunas áreas hoy día únicamente por medio de rociadas de DDT residual.

Las primeras aventuras en la exterminación de malaria y fiebre amarilla en las Américas se han discutido breviamente así como las causas de sus fracasos. En contraste, se ha citado el éxito de la campaña en Brasil para exterminar *Anófeles gambiae* y el progreso logrado en la eliminación del mosquito de la fiebre amarilla en el mismo país.

Se han mencionado algunas consideraciones teóricas con respecto a la exterminación de malaria con principal referencia a la prevención de transmisión. Se le ha dado importancia a la diferencia en énfasis entre los viejos y nuevos métodos de control de malaria. El método actual de ataque es dirigido contra el parásito de la malaria en el mosquito y no contra los estados jóvenes del insecto vector, o contra el parásito de la malaria en el hombre a través del uso de drogas antipalúdicas.

El paso preliminar en el uso del nuevo método se efectuó empleándose rociadas de "pyrethrum" para librar las moradas de mosquitos infectados o potencialmente infectados. "Pyrethrum" ha sido reemplazado por DDT como un insecticida residual pues éste es más efectivo y los intervalos entre rociadas son más largos resultando en menos costo per capita. El éxito del DDT residual depende de los hábitos domésticos del mosquito vector. La campañas recientes en los Estados Unidos, Venezuela, Guiana Británica y Brasil han demostrado que los tres vectores principales en estas áreas, *Anófeles quadrimaculatus*, *A. darlingi* y *A. albimanus* entran a las casas fácilmente y son por lo tanto fácilmente controlados con rociadas de DDT residual. Este hecho forma la base del programa nacional de control de malaria en el hemisferio occidental.

Se ha mencionado el éxito de la campaña con rociadas de DDT en Venezuela y se han relatado los factores que lograron este fin. La campaña en la Guiana Británica ha demostrado ser muy satisfactoria pues el único vector aquí, *Anófeles darlingi*, ha sido completamente exterminado en el área rociada.

Se ha señalado que DDT es efectivo contra el mosquito de la fiebre amarilla así como contra el *Anófeles*. Este hecho hace aconsejable la combinación de servicios de control de malaria con servicios de control anti-aegypti y además, para que "eventualmente la orientación y ejecución de los programas generales de desinfestación de casas, llevados a cabo hoy día por varios servicios administrativos descentralizados descansen en manos de un servicio solamente."

El nuevo programa de exterminación de malaria en Argentina ha sido considerado

extensamente dando importancia al hecho que rociadas de DDT constituyen la única medida de control empleada hoy día. El estado de las operaciones de control de malaria en Ecuador y en siete países centroamericanos ha sido discutido y las campañas en varias otras repúblicas latinoamericanas han sido breviamente bosquejadas.

La gran extensión del uso del notablemente efectivo insecticida residual DDT como un medio de controlar la malaria durante los últimos cinco años hace que el autor exprese lo siguiente: "No es mucho el anticipar que el resto del trabajo de exterminación de malaria pueda lograrse durante los próximos cinco años, si se toma completa ventaja de los servicios de las organizaciones internacionales responsables de la coordinación de actividades sanitarias en las Américas."

CRITERIA OF MALARIA ERADICATION

At the annual meeting of the National Malaria Society held in Memphis, Tennessee, from November 6 to 9, 1949, the Communicable Disease Center, U. S. Public Health Service, requested the Society to take steps necessary for the formulation of criteria to be used in determining when malaria ceases to be an endemic disease. The Board of Directors of the Society recommended that the President appoint a committee to define and draft such criteria. This action was endorsed by the Society with the proviso that the final committee report be circularized to Society members for their comments.

President Paul F. Russell appointed the following to serve on the Committee: Dr. E. H. Hinman, Chairman; Dr. Charles N. Leach, Dr. E. F. Knipling, Mr. David Lee, Dr. E. C. Faust, Mr. Ralph S. Howard, Members; Dr. T. H. G. Aitken and Dr. Arnoldo Gabaldon, Corresponding Members; Professor John M. Henderson, Dr. F. C. Bishopp, Dr. Mark F. Boyd, Dr. Fred L. Soper, Dr. Thomas F. Sellers, Consultants; and Dr. Paul F. Russell, Dr. Justin M. Andrews and Dr. Martin D. Young, *ex officio* Members.

The Committee held two meetings during the ensuing year and as a result of these deliberations presented a Final Report to the Board of Directors on November 6, 1950. Copies of the report were made available during the next two days and on November 8, 1950, the Society voted the adoption of the Final Report.

Because of its cognate relation to the Symposium on "Nation-wide Malaria Eradication Projects in the Americas", it is reproduced with the papers presented at the symposium.—*Editor.*

FINAL REPORT OF THE NATIONAL MALARIA SOCIETY COMMITTEE ON CRITERIA TO DETERMINE WHEN MALARIA CEASES TO BE AN ENDEMIC DISEASE

As endemic malaria approaches the vanishing point within any large area, the localization of residual cases becomes of paramount importance. The most objective means of establishing cases of malaria is to produce acceptable evidence of parasitemia. To identify primary indigenous cases, the basis of endemicity, adequate epidemiologic data must be available.

CRITERION OF CESSATION OF MALARIA ENDEMICITY

Malaria may be assumed to be no longer endemic in any given area when no primary indigenous case has occurred there for three years, if reporting, including the name and address of the patient and diagnosing physician, and case finding are actively promoted and adequate investigations are carried out.

This opinion is rendered with the full knowledge that relapses of malaria may occur after periods of latency exceeding three years, but it is believed that these instances will be so infrequent as to be inconsequential.

DEFINITIONS

1. Primary indigenous malaria is defined as the first parasite-positive evidence of infection, resulting from natural (mosquito) transmission within the given area.
2. Adequate investigation is defined as the epidemiologic investigation and appraisal of each reported case by qualified personnel. This involves verifying the diagnosis and determining if possible where and when the transmission occurred.

RECOMMENDATIONS

1. All slides considered to be positive should be submitted to a national depository for review.
2. The Public Health Service (Communicable Disease Center) should be designated as the national depository.
3. Consultants, including non-governmental authorities, should be appointed to review all controversial slides.
4. Non-governmental consultants should periodically examine and review the epidemiologic appraisals.
5. Inasmuch as determining the cessation of malaria transmission is dependent upon adequate epidemiologic intelligence, it is essential that every effort should be made to stimulate morbidity reporting, parasitologic confirmation, and case appraisal.

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